MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 96 No. 4

1936 FEBRUARY 14

ANNUAL GENERAL MEETING

Mr. J. H. Reynolds, President, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The President said :—

We are met to-day under the shadow of a great loss—a great loss to the whole world, but especially to this country and the British Empire. His late Majesty King George V graciously consented to become Patron of this Society in 1910, and at the Council Meeting this afternoon an Address of condolence and loyalty to His Majesty King Edward VIII and an Address of sympathy to Her Majesty Queen Mary were approved by the Council. I will now read these Addresses.

To the King's Most Excellent Majesty.

May it please Your Majesty:

We, the President, Council, and Fellows of the Royal Astronomical Society, beg leave humbly to approach Your Majesty to express our sorrow and respectful sympathy on the death of our beloved Sovereign, King George V. His late Majesty had been graciously pleased to honour our Society by becoming its Patron, an honour which had also been accorded to us by Their Majesties King Edward VII, Queen Victoria and King William IV.

We are deeply conscious of the kingly courage and wisdom with which His Majesty guided the affairs of the Nation in very troubled times. His care for His subjects and His sympathy with them in their difficulties endeared Him to all their hearts.

We further beg leave to offer our dutiful congratulations to Your Majesty on Your accession to the throne of Your ancestors, being fully assured of the continuance of that active devotion to the welfare, not only of this country but of the whole Empire, which Your Majesty has shown as Prince of Wales. And we pray that, under the blessing of God, Your Majesty may be granted health, happiness and a long and prosperous reign.

To the Queen's Most Excellent Majesty.

MAY IT PLEASE YOUR MAJESTY:

We, the President, Council and Fellows of the Royal Astronomical Society, humbly beg leave to approach Your Majesty with the expression of our deep sorrow at the death of our beloved Sovereign, King George V, the Patron of our Society.

We beg to tender our dutiful sympathy and continued devotion to Your Majesty, and to assure Your Majesty that it is our heartfelt prayer that Almighty God will vouchsafe You consolation in Your bereavement.

These Addresses were agreed to, the Fellows present standing in silence during the reading of them by the President.

The President drew attention to a bust of Galileo presented by Dr. A. Parr.

The election by the Council of the following Fellows was duly confirmed :—

Ibrahim A. N. Abul-Nasr, M.A., 16 Lawrence Street, Glasgow, W. 2 ;

John Grant Bruce, Curator of the Mills Observatory, Dundee, and 66 Nethergate, Dundee ; and

Frank Edmund Stafford, O.B.E., F.R.G.S., East India United Service Club, 16 St. James's Square, London, S.W. 1.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Eric Frank Baxter, M.A., M.Sc., Lecturer in Applied Mathematics, Durham Colleges in the University of Durham (proposed by G. R. Goldsbrough) ; and

Mademoiselle Lucy Foltz, L'Observatoire, Digne, B.A., France (proposed by R. B. Cafferata).

The President announced that a letter of congratulation had been sent from the Council to Mr. Richard Inwards on the completion of seventy-five years of Fellowship of the Society.

The Report of the Auditors of the Treasurer's accounts for the year 1935 was read, and is given on p. 281.

The Annual Report of the Council was partly read.

An Address on the award of the Gold Medal was delivered by the President, after which the Gold Medal was handed to Mr. M. Hasegawa, of the Japanese Embassy, for transmission to Professor H. Kimura, to whom it had been awarded for his valuable work on the variation of latitude (see p. 390).

The President then delivered an Address on "The Galactic Nebulæ" (see p. 393).

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the Report of the Auditors and the President's Addresses.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 400.

The thanks of the Meeting were given to the retiring members of Council, and also to the Scrutineers of the ballot.

Mr. Evershed showed slides illustrating the behaviour of various photographic emulsions.

Dr. Steavenson showed lantern slides which have been added to the Society's collection during the past year.

REPORT OF THE COUNCIL TO THE HUNDRED AND SIXTEENTH ANNUAL GENERAL MEETING OF THE SOCIETY.

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Honorary Member	Fellows		Associates	Total
				Compounders	Annual Subscribers		
1934 December 31	1	4	1	217	669	45	937
Since elected	...	...	...	+1	+37	+4	...
Deceased, 1935	...	...	...	−3	−10	−2	...
Deceased, 1930–34, not reported till 1935	...	...	...	−2	− 1	...	...
Resigned	...	...	...	...	− 9	...	...
Since compounded	...	...	...	+6	− 6	...	...
Removed from list	...	...	...	...	− 4	...	...
1935 December 31	1	4	1	219	676	47	948

(Six Associates are also Fellows, and are therefore counted twice in the above table.)

RECEIVED

	£ s. d.	£ s. d.
Balances, 1935 January 1 :—		
In hand of Assistant Secretary on Petty Cash Account	4 9 10	
At Bankers', on Current Account	581 14 3	
Cheque not yet credited	6 6 0	
At Bankers', on "C" Account (Trust Funds)	111 17 2	
		704 7 3
Received on account of Dividends :—		
£1250 Metropolitan Consolidated 3% Stock	37 10 0	
£2000 Swansea Corporation 3½% Stock	70 0 0	
£2287, 6s. 9d. East Indian Railway 3% Debenture Stock	53 3 4	
£5125 London, Midland and Scottish Railway 4% Debenture Stock	158 17 6	
£750 London, Midland and Scottish Railway 4% Consolidated Preference Stock	26 3 1	
£2400 Gas Light & Coke Co. 3% Debenture Stock	55 16 0	
£2000 Commercial Gas Co. 3% Debenture Stock	46 10 0	
£1035 Agricultural Mortgage Corporation 4½% Debenture Stock, 1961–91	36 2 0	
£695, 16s. Conversion Loan 3½% Stock, 1961	24 7 0	
£419, 17s. 11d. Conversion Loan 4½% Stock, 1940–44	18 17 10	
£700 Birmingham Corporation 3% Inscribed Stock, 1947	21 0 0	
£496 Consolidated Loan 4%	19 16 8	
£2000 New Zealand 3½% Loan, 1940	70 0 0	
£1000 Hull Corporation 4½% Redeemable Stock, 1952–72	45 0 0	
£800 War Loan 3½% Inscribed Stock...	28 0 0	
£500 New South Wales 4% Stock, 1942–62	15 10 0	
£1000 Central Electricity Board 4½% Stock, 1957–82	34 17 6	
Income Tax refunded, 1934 April–1935 April	123 2 7	
	884 13 6	
Sales of Publications £269 12 3		
Reprints 97 16 0		
Advance payments for Franklin-Adams Charts 81 0 0		
	448 8 3	
Sales of Photographs	46 9 0	
Sales of Duplicate Books from Library	38 2 6	
Miscellaneous Receipts :—		
London Mathematical Society, expenses of Meetings, etc. £30 0 0		
Assistant Secretary and Clerk, Pension Premiums ... 19 5 0		
Geological Society, refund on Subscription to Wollaston Memorial, 1933 ... ... 0 2 9		
Postages repaid 5 15 3		
Use of Telephone 0 14 0		
Excess on Subscriptions... ... ... 0 5 9		
	56 2 9	
		1473 16 0
Received on account of Subscriptions :—		
567 Annual Contributions for 1935 (including 2 Institutional Membership Fees)	1190 14 0	
1 ditto. Part Subscription (on account)	0 16 0	
20 Annual Contributions for 1936 in advance (including 1 Institutional Membership Fee)...	42 0 0	
38 Admission Fees	79 16 0	
37 First Contributions	77 14 0	
Arrears paid off :—		
8½ for 1933... ... ... £17 17 0		
31½ for 1934... ... ... 66 3 0		
	84 0 0	
		1475 0 0
Compositions (initial and reduced)		126 0 0
Trust Fund Dividends :—		
£1212, 13s. 3d. East Indian Railway 3% Debenture Stock... ...	28 4 0	
£542, 18s. 2d. India 3½% Stock	19 0 0	
£965 Agricultural Mortgage Corporation 4½% Debenture Stock, 1961–91	33 13 2	
£1004 Consolidated Loan 4%	40 3 2	
Donation from General Fund (balance of George Darwin Lecture Fee)	9 16 10	
Income Tax refunded, 1934 April–1935 April	17 19 0	
		148 16 2
		£3927 19 5

Examined and found correct.
(Signed) L. M. MILNE-THOMSON.
W. M. WITCHELL.

1936 *January* 11.

Account

PAID

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	268	6	8			
Clerk: Salary	188	15	0			
Assistant Secretary and Clerk, for work done for London Mathematical Society in 1934	10	0	0			
Ditto in 1935	10	0	0			
Pension Premiums for Assistant Secretary and Clerk	57	15	0			
Porter and Wife: Wages	153	17	6			
Health and Unemployment Insurance	6	18	8			
				695	12	10
Licence for Porter	0	15	0			
Fire and Accident Insurance	14	4	3			
Telephone	15	10	10			
Telegraphic Address	2	0	0			
Time Signal	5	2	8			
Water Rate	12	12	0			
				50	4	9
Postage and Packing:—						
Monthly Notices, etc.	121	3	5			
Office Postages	55	10	6			
				176	13	11
Printing, etc.:—						
Monthly Notices (Vol. **95**, Nos. 1–9)	933	4	4			
Geophysical Supplement (Vol. **3**, No. 7)	33	19	7			
List of Fellows, 1935	41	6	10			
Reprints	145	11	0			
Miscellaneous	57	15	9			
Photo-engraving:—						
Monthly Notices £64 3 6						
Geophysical Supplements 1 3 0						
	65	6	6			
				1277	4	0
Reproduction of Photographs for sale				58	15	7
Stationery and Office Expenses	23	5	9			
Library Equipment, Binding, Purchase of Books (General Fund)	51	5	3			
Purchase of Books (Potter Fund)	6	17	8			
Reproduction of Presidents' Portraits	18	8	8			
Reproduction of Early Parts of *Monthly Notices* by "Replika" Process	10	13	0			
Subscription to International Telegrams Bureau	2	14	11			
Jubilee Address to H.M. the King	2	0	0			
Share of Decoration of Courtyard for Jubilee	17	10	0			
Advertisement of Duplicate Books for Sale	1	7	6			
Porter's Uniform	5	10	0			
Subscription to Committee on Library Co-operation	1	1	0			
Authorised Travelling Expenses	9	6	3			
Heating and Lighting	106	11	10			
Fittings and Repairs	93	1	10			
Balance of George Darwin Lecture Fee	9	16	10			
House Expenses and Laundry	19	19	10			
Graticules for Franklin-Adams Charts	10	4	2			
Expenses of R.A.S. Meetings and Committees	18	7	5			
Expenses of Geophysical Meetings	3	15	2			
Expenses of L.M.S. Meetings	6	9	1			
Miscellaneous Expenditure	9	2	3			
Bank Charges and Cheque Books	2	15	7			
				430	4	0
Purchase of Book from Funds raised by Sale of Duplicate Books				4	14	6
				2693	9	7
Expenditure on Trust Accounts:—						
George Darwin Lecture Fee	50	0	0			
Turnor and Horrocks Fund (Library)	15	14	4			
Harry Watson Fund (Library)	23	10	10			
H. Jackson-Gwilt Fund	25	0	0			
				114	5	2
Balances, 1935 December 31:—						
In hand of Assistant Secretary on Petty Cash Account	2	7	5			
At Bankers', on Current Account	938	1	1			
At Bankers', on "C" Account:—						
Trust Funds £146 8 2						
Proceeds of Sales of Duplicate Books 33 8 0						
	179	16	2			
				1120	4	8
				£3927	19	5

Revenue

	£	s.	d.	£	s.	d.
To General Expenditure as per Cash Account	2693	9	7			
,, Reserve for Accounts due but not presented...	250	0	0			
	2943	9	7			
Less Reserve for Accounts due 1934 now written back ...	145	0	0			
				2798	9	7
,, Amount transferred to Composition Fees Reserve Fund in 1935...				126	0	0
,, 14 Annual Contributions in Arrear written off	29	8	0			
,, 12 Annual Contributions 1935 written off as per contra ...	25	4	0			
				54	12	0
,, Due for Reprints, 1934, written off				0	9	6
,, Excess of Income over Expenditure, 1935				130	13	4
				£3110	4	5

Examined and found correct.

(Signed) L. M. MILNE-THOMSON.
W. M. WITCHELL.

1936 *January* 11.

Account, 1935

		£	s.	d.	£	s.	d.
By Subscriptions—							
567	Annual Contributions 1935, including 2 Institutional Membership Fees	1190	14	0			
1	Part ditto (on account)	0	16	0			
17½	ditto, 1935, paid 1931–34 (including 1 Institutional Membership Fee), now matured	36	15	0			
68½	ditto (*less* 16*s.*) (including 1 Institutional Membership Fee), outstanding	143	1	0			
12	Contributions for 1935 due, but unpaid, in respect of Fellows died, resigned, or names removed, and written off per contra	25	4	0			
					1396	10	0
,, 37	First Contributions, 1935, at 2 guineas				77	14	0
,, 38	Admission Fees, 1935				79	16	0
,, 1	Composition Fee (on election)	31	10	0			
,, 1	ditto, at 30 guineas	31	10	0			
,, 5	ditto, reduced	63	0	0			
7					126	0	0
,,	6% of Composition Fees Reserve Fund as per Balance Sheet, transferred to Current Revenue				43	8	4
,,	Sundry Debtors, 1935				3	8	5
,,	Dividends, Sales of Publications and Photographs, and Miscellaneous Receipts, as per Cash Account	1473	16	0			
Less	Payments due 1934 (£19, 19*s.* 11*d.*, *less* 9*s.* 6*d.* written off, and 19*s.* 9*d.* still outstanding) £18 10 8						
	Advance payments for *Monthly Notices*, Vol. 96 43 19 9						
	Advance Payments for Franklin-Adams Charts 81 0 0						
	Income Tax (General Fund) 1934 April–December, refunded in 1935 76 11 5						
		220	1	10			
					1253	14	2
,,	Payments for *Monthly Notices*, Vol. 95, received in 1934 and now matured				52	5	3
,,	Income Tax (General Fund) deducted at source 1935 April–December, not yet refunded				77	8	3
					£3110	4	5

Balance Sheet

LIABILITIES

	£ s. d.	£ s. d.
20 Subscriptions for 1936, paid in 1935		42 0 0
Sundry Creditors for Accounts due but not presented ...		250 0 0
Cash Balances (Income) of Trust Funds—		
Turnor and Horrocks Fund	4 18 10	
Harry Watson Fund	42 17 5	
Lee and Janson Fund	46 15 11	
Hannah Jackson Fund	31 14 5	
George Darwin Lectureship Fund	20 1 7	
		146 8 2
Trust Funds (Capital), as per contra		2964 0 0
Income Tax on Trust Funds, 1935 April–December, not yet refunded, as per contra		15 18 1
Special Fund (Capital), as per contra		1460 0 0
Composition Fees Reserve Fund—		
As at 1934 December 31	597 12 8	
Received in 1935	126 0 0	
	723 12 8	
Less 6% transferred to current revenue	43 8 4	
		680 4 4
Advance payments for Franklin-Adams Charts		81 0 0
Advance payments for *Monthly Notices*, Vol. 96		43 19 9
Credit for overpayment on publications, 1932		0 11 0
General Fund—		
As at 1934 December 31	17,505 0 0	
Add Excess of Income, over Expenditure, 1935... ...	130 13 4	
		17,635 13 4
		£23,319 14 8

Examined and found correct.

(Signed) L. M. MILNE-THOMSON.
W. M. WITCHELL.

1936 *January* 11.

1935 *December* 31

ASSETS

	£ s. d.	£ s. d.
Sundry Debtors for Subscriptions in Arrears—		
19½ for 1934 (*less* 13*s.*)	40 6 0	
68½ for 1935 (*less* 16*s.*)	143 1 0	
		183 7 0
Sundry Debtors, 1933		0 19 0
Sundry Debtors, 1934		0 19 9
Sundry Debtors, 1935—		
Due for Publications	2 6 6	
Due for Reprints	0 8 6	
Due for Photographs	0 11 0	
Due for Postages	0 2 5	
		3 8 5
Investments of General Fund, valued as in 1934 Balance Sheet		17,493 9 6
Investments of Special Fund, valued at cost		1460 0 0
Investments of Trust Funds, valued as in 1934 Balance Sheet		2964 0 0
Income Tax 1935 April–December, deducted at source and not yet refunded—		
General Fund	77 8 3	
Trust Funds	15 18 1	
		93 6 4
Sundry Balances—		
In hand of Assistant Secretary on Petty Cash Account ...	2 7 5	
At Bankers', on Current Account	938 1 1	
At Bankers', on "C" Account—		
Trust Funds £146 8 2		
Proceeds of Sales of Duplicate Books ... 33 8 0		
	179 16 2	
		1120 4 8
		£23,319 14 8

Astronomical and other Manuscripts, Books, Prints, Photographs and Instruments.
Furniture, etc.
Stock of Publications and Photographs for sale.
Four Bronze (Jackson-Gwilt) Medals.
} Not valued.

INVESTMENTS

As at 1935 December 31

General Fund

£1250 Metropolitan Consolidated 3-per-cent. Stock, 1941.
£2000 Swansea Corporation 3½-per-cent. Stock.
£2287, 6*s.* 9*d.* East Indian Railway 3-per-cent. New Debenture Stock.*
£5125 London, Midland and Scottish Railway 4-per-cent. Debenture Stock.*
£750 London, Midland and Scottish Railway 4-per-cent. Preference Stock.*
£2400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.*
£2000 Commercial Gas Co. 3-per-cent. Consolidated Debenture Stock.*
£496 Consolidated 4-per-cent. Loan, 1967.
£500 Agricultural Mortgage Corporation, Ltd., 4½-per-cent. Debenture Stock, 1961–91.*
£1000 Hull Corporation 4½-per-cent. Redeemable Stock, 1952–72.
£1000 Central Electricity Board 4½-per-cent. Stock, 1957–82.*
£2000 New Zealand 3½-per-cent. Loan, 1940.
£700 Birmingham Corporation 3-per-cent. Inscribed Stock, 1947.
£800 War Loan 3½-per-cent. Inscribed Stock.
£500 New South Wales 4-per-cent. Stock, 1942–62.*

Grove-Hills Special Fund

£419, 17*s.* 11*d.* Conversion Loan 4½-per-cent., 1940–44.
£695, 16*s.* 0*d.* Conversion Loan 3½-per-cent., 1961.
£535 Agricultural Mortgage Corporation, Ltd., 4½-per-cent. Debenture Stock, 1961–91.*

Trust Funds

£1212, 13*s.* 3*d.* East Indian Railway 3-per-cent. New Debenture Stock.*
£542, 18*s.* 2*d.* India 3½-per-cent. Stock.
£1004 Consolidated 4-per-cent. Loan, 1967.
£965 Agricultural Mortgage Corporation, Ltd., 4½-per-cent. Debenture Stock, 1961–91.*

* Taxed at source.

REPORT OF THE AUDITORS FOR THE YEAR 1935

We have examined the Treasurer's account of receipts and expenditure, the Revenue Account and the Balance Sheet for the year 1935, and have certified them to be correct. The investment holdings have been certified either by the Bank of England or by the Westminster Bank.

The excess of income over expenditure, as shown by the Revenue Account, is approximately £130. The corresponding amount in 1934 was £161. In this connection we note two items of expenditure of a non-recurring character, namely, £17, 10*s*. for the Society's share of the cost of decorating the courtyard of Burlington House for the Jubilee and £18, 8*s*. 8*d*. for the completion of the reproduction of Presidents' portraits which had faded. The rather large item for Fittings and Repairs is in part accounted for by redecoration of the basement and the replacement of the vacuum cleaner.

The sum held in reserve in respect of the liability to Fellows who have compounded has increased from £597 to £680.

During the past year several books from the main library which are duplicated in the Grove-Hills collection have been sold. The books sold have been in all cases inferior in condition to the duplicates retained. From the proceeds of the sales it is proposed to fill gaps in the Society's collection of early books, and a work of Snellius, *Descriptio Cometæ* 1618, has already been purchased.

No further books are reported as missing from the library since the last audit, but, on the other hand, none of those then missing has been found.

A small cabinet has been provided to contain the Tomkins collection of Moon negatives, and the collection is now available for loan to Fellows.

A list has been laid on the table containing the names of those Fellows who are still in arrear for sums due on 1935 January 1, with the amount due against each Fellow's name.

We have inspected the Society's premises. The premises, generally, appear to be in satisfactory condition, but we wish to draw attention to the worn state of carpets, and particularly to the bad condition of the Council Room carpet.

The work of auditing has been greatly lightened by the use of an adding machine hired for the purpose. We suggest that the purchase of a similar machine for ordinary use in the Society's office is desirable and would be an economy.

We have received from the Assistant Secretary all the information and explanations we have required.

(Signed) L. M. Milne-Thomson.
W. M. Witchell.

1936 *January* 11

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY

The John Lee Gift: In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Parsons Gift (1922): The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock 1929–47, in memory of his father, the 3rd Earl of Rosse, who made the 6-foot reflector, and who died 1867 October 31.

The Grove-Hills Bequest (1922): Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early astronomical and mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Lindemann Bequest (1931): A. F. Lindemann, Esq., bequeathed to the Society the sum of £1000, free of legacy duty.

The Archdeacon Potter Bequest (1933): Archdeacon Beresford Potter bequeathed to the Society a 3/88th share of his residuary estate, amounting to £318, 16*s.* 2*d.*

THE GROVE-HILLS SPECIAL FUND

In 1923 the Treasurer, Col. Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. The total amount received from all sources (including dividends on the investments representing the fund) has been £1913, 1*s.* 11*d.*, of which £1480, 2*s.* 10*d.* has been invested and is now represented by £535 Agricultural Mortgage 4½ per cent., £419, 17*s.* 11*d.* Conversion Loan 4½ per cent. 1940–44, and £695, 16*s.* Conversion Loan 3½ per cent. 1961.

THE ARCHDEACON POTTER FUND

The late Archdeacon Beresford Potter, who died 1931 May 10, bequeathed to the Society a 3/88th share of his residuary estate. This legacy was received in 1933, and now stands invested in £300 3½ per cent. War Stock, the cash balance of £17, 15*s.* 2*d.* being expended on the library in 1934. The Council resolved to allocate the dividends from this Fund for the purposes of the library.

	£	*s.*	*d.*		£	*s.*	*d*
1935 Jan. 1. Balance of Fund	5	6	2	1935. Purchase of Books ...	6	17	8
1935. Dividends, War Stock 3½ per cent.	10	10	0	1935 Dec. 31. Balance of Fund	8	18	6
	£15	16	2		£15	16	2

TRUST FUNDS

The Lee and Janson Fund : In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1935 Jan. 1. Balance of Fund	36	15	3	1935 Dec. 31. Balance of Fund	46	15	11
1935. Dividends, East Indian Railway ...	7	15	8				
Income Tax, 1934 April–1935 April, refunded ...	2	5	0				
	£46	15	11		£46	15	11

The Turnor Fund and the Horrocks Memorial Fund : In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s*. East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s*., the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks : to this the Society added the sum of £55, 15*s*., and the whole now stands in £103, 6*s*. East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the library.

	£	*s*.	*d*.		£	*s*.	*d*.
1935 Jan. 1. Balance of Fund	3	12	2	1935. Purchase of Books ...	15	14	4
1935. Dividends, East Indian Railway ...	13	4	4	1935 Dec. 31. Balance of Fund	4	18	10
Income Tax, 1934 April–1935 April, refunded ...	3	16	8				
	£20	13	2		£20	13	2

The Harry Watson Memorial Fund : In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s*. 2*d*. India 3½-per-cent. stock. In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s*. to the Society, which now stands invested in £965 Agricultural Mortgage 4½-per-cent. Stock. The Council resolved that these two sums should together constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books.

	£	*s*.	*d*.		£	*s*.	*d*.
1935 Jan. 1. Balance of Fund	3	19	9	1935. Purchase of Books ...	23	10	10
1935. Dividends, India 3½ per cent.	19	0	0	1935 Dec. 31. Balance of Fund	42	17	5
Dividends, Agricultural Mortgage 4½ per cent.	33	13	2				
Income Tax, 1934 April–1935 April, refunded	9	15	4				
	£66	8	3		£66	8	3

The Hannah Jackson (née Gwilt) Fund : In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock ; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	*s.*	*d.*		£	*s.*	*d.*
1935 Jan. 1. Balance of Fund	47	8	5	1935 Award to Mr. W. F. Gale	25	0	0
1935. Dividends, East Indian Railway ...	7	4	0	1935 Dec. 31. Balance of Fund	31	14	5
Income Tax 1934 April–1935 April, refunded ...	2	2	0				
	£56	14	5		£56	14	5

The George Darwin Lectureship Fund : In 1926 June Sir James Jeans presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George Darwin Lectureship*, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

This sum now stands in £1004 Consolidated 4-per-cent. Loan. The income is annually applied to the purposes of the Trust in accordance with the terms of the Deed of Gift.

	£	*s.*	*d.*		£	*s.*	*d.*
1935 Jan. 1. Balance of Fund	20	1	7	1935 May. Lecture Fee ...	50	0	0
Dividends, Consolidated 4 per cent. Loan	40	3	2	1935 Dec. 31. Balance of Fund	20	1	7
Donation from General Fund	9	16	10				
	£70	1	7		£70	1	7

CELESTIAL PHOTOGRAPHS

The following have been added to the list of Celestial Photographs reproduced by the Society for sale to Fellows :—

R.A.S. Serial No.	Ref. No.	
484	J 95.	N.G.C. 891, Neb. H V 19 Andromeda. Ritchey, Mount Wilson. 60-inch Reflector, *f.l.* 299 inches. 1916 Nov. 23–24. Exp. 7¼ h.
485	I 48.	Nebula I.C. 59–63, n.f. γ Cas. M. de Kerolyr, Forcalquier. 32-inch Reflector, *f.l.* 192 inches. 1934 Oct. 13. Exp. 2 h. 15 m.
486	L 33.	Milky Way, Scorpius. α. 16^h ; δ, $-28°$. F. E. Ross, Yerkes. 5-inch lens, *f.l.* 35 inches. 1931 May 18. Exp. 3 h.

R.A.S. Serial No. Ref. No.

487 L 34. Milky Way, Ophiuchus, Scorpius. α, 17^h; δ, $-28°$. F. E. Ross, Yerkes. 5-inch lens, *f.l.* 35 inches. 1931 May 24. Exp. 3 h. 18 m.

488 L 35. Milky Way, Aquila. α, 19^h; δ, $+15°$. F. E. Ross, Yerkes. 5-inch lens, *f.l.* 35 inches. 1931 July 17. Exp. 4 h.

489 L 36. Milky Way, Cygnus. α, $20^h\ 17^m$; δ, $+39°$. F. E. Ross, Yerkes. 5-inch lens, *f.l.* 35 inches. 1930 Oct. 13. Exp. 3 h.

490 P 9. Nova Persei (1901). 1934 Oct. 14. Spectrum, 1934 Nov. 4–6. Mount Wilson.

491 I 49. Nova Persei (1901). 1917 Nov. 15 and 1933 Oct. 14. Mount Wilson.

PUBLICATIONS OF THE SOCIETY

During the past year the Society has published *Monthly Notices*, vol. 95 ; *Geophysical Supplements*, vol. 3, No. 7 ; and List of Fellows, 1935.

OBITUARY

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Bernhard Richard Baumgardt
Bahne Bonniksen
James Garton Bower
Herbert Brown
John Thomas Windmill Claridge
William Sadler Franks
Lionel G. W. Guest
George Hall Hamilton
Charles Monro Hector
*Sydney Turner Klein
Gertrude Longbottom
Hector Munro Macdonald
James Duncan McNeile
*John Ellis Owen
†John Bagnold Smith
William Strachan
Associates :—Edwin Brant Frost
Charles Edward St. John

HENRY OSMUND BARNARD ‡ was born in Mauritius in 1869. After being educated at Royal College, Mauritius, and University College School, London, he entered the R.I.E.C., Cooper's Hill, in 1887, whence he passed out second on the list in 1890. Towards the end of the same year he was appointed to the Ceylon Survey Department, and after several years' service in the field he was brought permanently into the Head Office in Colombo at the beginning of 1899.

His life in Colombo was a busy one. In addition to being superintendent of Trigonometrical Surveys and being in charge of all the meteorological work in Ceylon, he was Government Referee for patents. He also did a great deal of voluntary work for the Widows' and Orphans' Pension Fund. It was entirely due to his efforts that an observatory was built and equipped in Cinnamon Gardens. Previous to its erection the method used for enabling ships' officers to check their chronometers was crude ; the time was cabled through in advance from Madras, and at 4.15 p.m. a semaphore arm was dropped by hand and a gun fired. After the erection of the observatory an electrically operated Time Ball became available.

* Died 1934. Death not reported until 1935.
† Died 1930. Death not reported until 1935.
‡ Death announced in 1934 Annual Report (*M.N.*, **95**, 317, 1935).

In 1912 December ill-health compelled Barnard to retire. He settled in Paris and acted as a consulting engineer to several companies. After 1918 he devoted a large part of his time to the production of fused quartz and silica, and became a director and vice-president of the "Quartz et Silice" company. His spare time was devoted to research, one result being the "Barnard Co-ordinate Spiral Slide Rule."

In 1901 he had married Charlotte, daughter of Constant Rozé, Professor of Astronomy and Mathematics in Paris, and in 1930 he moved to England. He died on 1934 February 27, leaving a widow and three children.

He was elected a Fellow of the Society on 1901 January 11.

BERNHARD RICHARD BAUMGARDT died at his home in Los Angeles on 1935 June 19. By his death the Society lost a Fellow who played what was possibly a decisive part in the circumstances which eventually resulted in the erection at Mount Wilson of the 100-inch telescope.

Baumgardt was born in Liverpool in 1862, his father being Swedish and his mother Anglo-French. The family subsequently went to Sweden, where Baumgardt received his education. He specialised in Mathematics and Astronomy, and graduated at Strengas College. His uncle was in command of a sailing ship and this inspired him, after his graduation, to go to sea before the mast. For more than three years, in his uncle's and other ships, he followed the calling of a sailor. He then settled in Seattle and decided to become a United States citizen. Eventually he is found as the proprietor of a printing business in Los Angeles. His interest in Science led to his association with others of like tendencies, and in 1891 he was one of a small group who founded the Science Association of Los Angeles, a name which was soon changed to "The Southern California Academy of Sciences." He was the first Secretary of the organisation, and his connection with the Academy led him into a personal friendship with Mr. John D. Hooker. Hooker was a generous man of wealth with strong scientific sympathies, and a stalwart friend in need to the young Academy of Sciences in its early years. Eventually Hooker decided to build and endow a permanent home for the Academy, and Baumgardt began to look for a site. In the meantime, however, G. E. Hale laid before Hooker his scheme for erecting a 100-inch telescope. Hooker felt that he could not manage to finance both the telescope and the Academy building, and finally asked Baumgardt which project would be of greater benefit to Science. Baumgardt advised Hooker to back the telescope, an action which must have involved some degree of sacrifice.

It is of interest to note that Hooker eventually purchased for his nephew an interest in Baumgardt's printing business. The premises were afterwards destroyed by fire, in 1910, and the partners decided to wind up the business and retire. Thereupon Baumgardt took up lecturing and became a well-known professional lecturer.

Mrs. Baumgardt died in 1934 August and her husband did not survive her for long. He leaves two sons.

He was elected a Fellow of the Society on 1927 February 11.

BAHNE BONNIKSEN was born at Bov, in the Duchy of Schleswig, on 1859 October 25. He served his apprenticeship in watchmaking, and after a brief period spent in Copenhagen he came to London at the age of twenty-four, and eventually became a British subject in 1910. He died at Leamington Spa, Warwickshire, on 1935 March 5.

Bonniksen followed the career of a watchmaker. At an early stage the remarkable performances of the Tourbillon watches and chronometers in the Kew trials attracted his attention and admiration. These watches were costly and delicate, and Bonniksen set himself the task of making a watch which would combine the performance of the Tourbillon with the robustness of an ordinary lever watch. The result of these efforts was the successful Karrusel, or revolving escapement watch.

At a later period Bonniksen carried out extensive experimental investigations on the temperature compensation of balance wheels, but the development of mass production led him to the conclusion that the day of the individual craftsman in watchmaking was past, and more and more of his attention was devoted to other applications of mechanism. He invented an automatic gas lighting system, a motor-car speedometer and other appliances, but he always retained his interest in time-keeping and lamented the lack of theoretical knowledge on the part of the workers of the watch trade of this country. He busied himself with schemes for correcting this, and his own knowledge was always at the disposal of others. He was keenly interested in navigation and astronomy and was elected a Fellow of the Society on 1905 May 12.

JAMES GARTON BOWER was born at Norwich on 1854 October 11, and spent all his life in his native city. He was educated at King Edward VI. School, Norwich, and from thence he entered the firm of Messrs. Barnard, Bishop & Barnards, now known as Barnards, Ltd., The Norfolk Iron Works, and thus began an association which lasted for more than sixty years, thirty of which were fulfilled in the capacity of Managing Director and Chairman of the Company. One of the outstanding successes of his long life was the invention of the special looms for producing the world-famous mixed mesh wire-netting which did much to reduce the rabbit pest in Australia.

A man with a keen mind and possessing great powers of concentration, he was never concerned with how many hours he spent on a job so long as it was ultimately satisfactory. He was also a strong-minded man, sometimes perhaps to the point of obstinacy, and once he had formed an opinion was very difficult to move ; but, as the writer knows from experience, he nearly always proved right.

Bower was attracted to Astronomy at an early age, and seems to have studied the science in all its branches, but latterly his interest was more in the direction of the mechanical side of it, and during his life he became the owner of a large number of scientific instruments, one of the most important of which was the Isaac Roberts 20-inch reflector, made by Sir Howard Grubb, to which was attached a 7-inch refractor, made by Cooke. Previous to purchasing that instrument he possessed a 20-inch speculum mounted as

an altazimuth. This instrument was also of historic interest, as it originally belonged to James Nasmyth, the famous engineer and inventor of the steam hammer, and was used by him in the construction of the plaster models which illustrated the book, *The Moon*, by Nasmyth and Carpenter, published in 1874. This instrument was presented by Bower to the Science Museum in 1933, and may now be seen exactly as shown in Smiles' *Life of James Nasmyth.* In addition to these instruments Bower had formed a unique collection of scientific apparatus, including a beautiful orrery, formerly the property of H.M. King George III., and a perfect scale model of an equatorial telescope, the whole forming a veritable scientific museum. He owned a very fine workshop, and in his spare time at home he was always to be found busily engaged on some intricate and absorbing mechanical operation, and the work he turned out there was of the highest quality.

Apart from his calling in life, he was a man with many outside interests which he indulged so far as his official duties permitted. For many years he was a regular visitor at Wimbledon Tennis Tournaments, and almost every Saturday afternoon, summer and winter, he played tennis on his own lawn or the hard court at Mousehold Heath. He also did a good deal of yachting, and nothing gave him more pleasure than to entertain a party of friends on board the *S.Y. Sunmaid* and latterly the *S.Y. Abona*, both good sea-going yachts. For relaxing the mind from the cares of business he had a passion for detective stories, and scarcely ever left home without one or two such books in his bag.

He was a keen churchman, and was for many years churchwarden of St. Thomas' Church, Norwich, and his beautiful garden was often the scene of a fête in connection with various churches.

He was elected a Fellow on 1920 March 12, and was an original Member of the British Astronomical Association. He was also a Fellow of the Physical Society.

He married Helen Brook Rhodes, daughter of Dr. G. Winter Rhodes of Huddersfield, by whom he had three sons, two surviving him. The youngest son, Captain C. F. Bower, was killed in action in France in 1917.

At the time of his decease he was the Senior Member of the Norwich Income Tax Commission and Chairman of the Labour Assessment.

His death took place at Norwich on 1935 May 28, in his eighty-first year.

A. M. N.

HERBERT BROWN was born in London on 1860 May 12. The greater part of his life was spent in Enfield, where he was well known. He was for some years chairman of the Literary Union, an elder of the Presbyterian Church, and a prominent worker in the local Liberal Association. He was employed in the Law, and on his retirement, after fifty-two years with the same firm, he went to live at West Byfleet, in Surrey, where he died on 1935 March 7. He was twice married, his first wife having died in 1917. He married again in 1921. He leaves a widow and two daughters.

He was elected a Fellow of the Society on 1928 January 13.

The Rev. JOHN THOMAS WINDMILL CLARIDGE was born on 1854 September 16 at Stewkley, in Buckinghamshire, but lived his early years in Birmingham. After school days he became a divinity student at Queen's College in that city, where he graduated, and continued his studies later at Trinity College, Dublin, from which foundation also he obtained the degree of B.A. in 1883, and M.A. eleven years later. He was ordained Deacon in the Diocese of Worcester in 1878, Priest in 1879, and held curacies successively at Kingsbury, North Warwickshire and Cressage, Shrewsbury. From the latter position he was transferred in 1889 to Upton Cressett, Bridgenorth, where he was Rector until 1891, and then held the posts successively of Curate of Tamworth (1891–1903), of Swadincote, Burton-on-Trent, and of St. Mark, Winshell, Burton-on-Trent. He was appointed Vicar of Garthorpe, Melton Mowbray, in 1911, where he remained until his death.

John Claridge showed interest in astronomy from his youth, and it is family tradition that he made a creditable map of the heavens when only twelve years of age. Early in his clerical career he obtained an excellent 4-inch refracting telescope that he used for general inspection and examination of the objects of the sky, especially the Moon, but published no results of his observations beyond what might be contained in the occasional notes he contributed to the press. Mr. Claridge's aim was to create and sustain interest in astronomy locally, and to this end he wrote articles on current events, which were generally more than simple announcements, in the Melton, Grantham, and Birmingham journals. His local reputation may be inferred from the fact that on the occasion of the Newton bi-centenary celebration at Grantham in 1927 he helped with the arrangements. He was a member of the Selborne Society, and lectured much in connection with that organisation as well as in other capacities. He was a member of the British Astronomical Association and also of the Royal Astronomical Society of Canada.

Mr. Claridge was unmarried. He died, after a short illness which necessitated an operation, on 1935 September 14.

He was elected a Fellow of the Society on 1894 June 8. H. P. H.

WILLIAM SADLER FRANKS was born at Newark on 1851 April 26. During the early part of his life he was occupied in his father's business at Leicester, but he soon exhibited a preference for pursuits of a mechanical and scientific nature. At first chemistry and electricity claimed his chief attention ; but a glance through a friend's telescope turned his thoughts towards astronomy, and it was not long before he had an instrument of his own, mounted in a small home-made observatory of the Berthon type. After satisfying his curiosity by a little general star-gazing, Franks soon settled down to systematic work, choosing the study of star colours as his line of research. The first fruits of this work took the form of a "Catalogue of the Colours of 3890 Stars," which was communicated to the Society on his behalf in 1878 by the Rev. T. W. Webb. His interest in this branch of work persisted throughout his life, though he was otherwise occupied for a

great part of his observing career. He directed the Star-Colour Section of the Liverpool Astronomical Society and, later, that of the British Astronomical Association. He contributed many papers on the subject to the *Monthly Notices*, and as recently as 1921 undertook a revision of the colours of some 6000 stars at the request of the late Father Hagen, who published them in a volume of the *Specola Vaticana* in 1923. He acquired great skill in the estimation of star colours, and his results, attained by purely visual means with a small telescope, have been found to be in quite remarkable agreement with those derived more recently by measurements of intensity distribution in photographic spectra.

In 1892 Franks joined the late Dr. Isaac Roberts at Crowborough, and was there engaged in photographing nebulæ and star clusters with the 20-inch reflector, until the time of his employer's death in 1904. In this work he showed the same careful attention to detail as had characterised his previous visual observations. The applause which always greeted the appearance of the Crowborough photographs on the screen at Burlington House was often a virtual tribute to his personal skill and gave him much quiet satisfaction.

He left Crowborough in 1906 and went to live at Uxbridge for some years, during which time he had several small engagements connected with private observatories. He also assisted the late John Franklin Adams at Mervel Hill in the preparation of his star charts for publication.

From 1910 until the time of his death Franks was in charge of Mr. Frederick J. Hanbury's observatory at East Grinstead. Here the chief instrument was a 6-inch equatorial refractor by Cooke, and with it he made, during seven years, a series of micrometrical measures of wide double stars. These were published in various papers communicated to the Society in the years 1914–1920. In 1923 the Council awarded to him the Jackson-Gwilt medal of the Society for his work on the colours of the stars. He was by this time in his seventy-second year, but he continued to contribute occasionally to the *Monthly Notices*, his last paper, on Barnard's Dark Nebulæ, being published in 1930 January, when he was seventy-eight.

Franks, in whose character modesty was charmingly blended with enthusiasm, was probably little known to the present generation of astronomers ; but there was a time when his diminutive, almost gnome-like figure was often seen at the meetings of the Society, and those who were privileged to know him will retain a happy recollection of his delightful personality.

He died on 1935 June 19, in the eighty-fifth year of his age, leaving a widow, one son and two daughters. He was elected a Fellow of the Society on 1880 January 9.

W. H. S.

The Hon. LIONEL GEORGE WILLIAM GUEST, fourth son of the first Lord Wimborne, was born at Wimborne House, Arlington Street, St. James's, London, on 1880 November 16. His mother was a daughter of the seventh Duke of Marlborough. He was educated at Eton, being in Mr. A. C. Benson's house, and from there he went to Glasgow University

and came under the influence of Lord Kelvin. Finally, he went to Trinity College, Cambridge.

In the early days of his career (1901–1911) he was engaged in Canada on financial business. During this time he met the lady who became his wife, and in 1905 he married Flora, the daughter of the Hon. John Bigelow, who was American Ambassador in Paris when Abraham Lincoln was President of the United States.

On the outbreak of the Great War he joined the Royal Naval Volunteer Reserve, in which he served until 1916. He then transferred to the Royal Flying Corps, where he remained until 1918. For his war services he was awarded the O.B.E. (Military). On returning to civilian life he resumed his business activities and became a director of several important companies, including Guest's Trust, Ltd., The American Austin Car Co., to name only two.

From 1928 to 1931 he represented Mile End on the London County Council, and was ably assisted in this work by his wife, who was a very active worker among the women of East London.

Science always had an attraction for him, and although astronomy seems to have held first place, his interests were by no means confined to this branch of it, for he had a versatile mind which found an outlet in many inventions of an engineering character. Had these inventions been followed up they would probably have had revolutionary results. One invention may, perhaps, be mentioned. In conjunction with Captain H. O. Merriman, a Canadian electrical engineer, he constructed a gramophone for recording sounds over long distances, and this machine was used for the first time in Westminster Abbey at the funeral of the Unknown Warrior.

Guest was modest to a degree, and it was probably for this reason that so many of his ideas failed to fructify. Coupled with this characteristic was a charm of spirit rarely met with, and those who had converse with him could not help being inspired by his lofty outlook on life. Not long before he died he said, "I have loved the stars too well to dread the night." His sense of duty was profound, and no personal inconvenience was ever allowed to come between him and what he conceived to be his duty. He was a fully qualified engine-driver, and during the railway strikes of the last decade he volunteered for service on the Great Eastern Railway, as it then was, and was given charge of a locomotive in the London area.

During his lifetime he possessed a number of telescopes, his first being a 10-inch reflector of his own construction which took him ten years to make. Latterly he used an $8\frac{1}{2}$-inch Grubb equatorial with which he made a large number of double star observations, besides doing a good deal of work on the Sun with a Thorp-Beck spectroscope.

About 1930 his health began to suffer and he found it increasingly difficult to carry on night work; but not to be daunted, he set about designing an instrument of the *Coudé* type which would enable him to have the eye end in an enclosed shelter. Then early in 1935 Mr. W. Strachan of Bournemouth died, and Guest acquired the fine 9-inch Coudé telescope which Strachan had had constructed specially to meet his requirements by Cooke,

Troughton & Simms of York. This instrument he erected on the south side of his house, the eye end being brought into his study, where he would be able to work in complete comfort. But, alas! he was destined to make but little use of it; his illness took a serious turn and he passed away at Ferring on 1935 September 27. Almost his last words were: "I wish my life remembered, not in grief but as an inspiration."

He was elected a Fellow of the Society on 1925 January 9.

A. M. N.

GEORGE HALL HAMILTON was born in London, of American parents, on 1884 January 31. He was the son of John McLure Hamilton and Clara Augusta Hamilton (*née* Raiguel). He was brought to the United States in infancy, but returned to England to complete his education, and proceeded to Trinity College, Cambridge. He was appointed Professor of Astronomy at Bellevue College, Nebraska, in 1910. From 1917 to 1922 he was an astronomer at the Lowell Observatory, and from 1922 to 1924 he was attached to the Harvard Observatory and was at its Jamaica branch. From 1924 onwards he worked as a "free-lance." He was an enthusiastic observer of Mars, and an exponent of the hypothesis that the Planet is inhabited by intelligent beings.

SYDNEY TURNER KLEIN was born at Redhill, Surrey, on 1853 November 4. He was educated at Haileybury, and afterwards entered the firm of William Klein & Sons, corn-brokers, becoming a partner until his retirement in 1916. In 1880 he married Sara Elizabeth, daughter of the Rev. William Urwick, of Hampstead. His early married life was spent at The Red House, Stanmore, Middlesex, where he erected an observatory with an 18-inch reflector. In 1898 he moved the observatory to Hatherlow, Reigate.

Klein's interests were numerous and varied, but his favourite pursuits were astronomy and entomology. He was a Fellow of the Entomological Society and also of the Linnean Society. He was a keen yachtsman and an extensive traveller, and his love of natural history led him to be largely responsible for the formation in 1886 of the County of Middlesex Natural History and Science Society, of which he was Secretary and Treasurer. He was a prominent freemason, and was greatly interested in philosophy. During the war he became crippled with arthritis, and for the last fifteen years of his life was compelled to use a wheeled chair. During these years of invalidism his thoughts turned more and more to philosophy and the influence of science on human thought and behaviour, and he wrote many books expressing his views on life, among them being *Science and the Infinite* and *The Way of Attainment*. He died on 1934 October 8 at his home at Chelsfield, Kent, leaving two sons and four daughters. Mrs. Klein died in 1930.

He was elected a Fellow of the Society on 1881 January 14.

GERTRUDE LONGBOTTOM was one of the earliest women Fellows of the Society (as distinct from honorary members), being elected a few months after the granting of the Supplementary Charter enabling women to become Fellows. She was born in 1876, the only child of Barnard Longbottom, of Louth, Lincolnshire. Educated at the North London Collegiate Schools for Girls, she proceeded to Girton, where she distinguished herself by becoming a high wrangler. She then obtained a Fellowship at Bryn Mawr, Philadelphia, where she spent a few years. In 1915 she collaborated with Dr. J. K. Fotheringham in a paper on "The Secular Acceleration of the Moon's Mean Motion as determined from the Occultations in the Almagest" (*M.N.*, 75, 377).

In spite of poor health she undertook much social and religious work, and was an active member of the Methodist Church, where for twenty years she was much beloved by a large class of girls. For some years she was a Governor of the Louth Grammar Schools, and during the last year of her life she was Warden. She died on 1935 March 20, at Louth.

She was elected a Fellow of the Society on 1916 May 12.

HECTOR MUNRO MACDONALD, who was elected a Fellow on 1918 November 8, died at Aberdeen on 1935 May 16. He was born at Edinburgh on 1865 January 19, though his home was in Easter Ross in the parish of Fearn, where his boyhood was spent. Educated at Tain Royal Academy and Old Aberdeen Grammar School, he entered King's College of the University of Aberdeen in 1882. He graduated with first-class honours in Mathematics and Natural Philosophy, securing the premier University prizes, and proceeded to Cambridge, capping a brilliant undergraduate career by graduating as Fourth Wrangler, and in 1891 gaining the Smith's Prize.

In 1890 he was elected a Fellow of Clare College, and spent the next fourteen years in Cambridge in teaching, administration and research. Most of his published work has been in the field of Applied Mathematics, particularly on the topic of Electromagnetic Waves, though several important papers on subjects of Pure Mathematics appear under his name. In 1901 he was awarded the Adams Prize for an essay that formed the basis of his important book, *Electric Waves*, and in the same year he was elected a Fellow of the Royal Society. In recognition of his outstanding contributions to knowledge, particularly in wireless telegraphy and physical optics, the Royal Society conferred on him in 1916 the Royal Medal.

In 1904 he was elected to the Chair of Mathematics in the University of Aberdeen, and he remained in office in his Alma Mater up to his death after a short illness last year.

To the University of Aberdeen he was a tower of strength, being esteemed both for his success as a teacher and investigator and for the able and whole-hearted attention he devoted to the large share he undertook of University administration. Important changes in University policy and structure took place during his tenure of the Chair of Mathematics, and his sound judgment, pertinacity and attention to detail proved of the utmost value.

He was for many years a member of the University Court, and as convener of the Edilis Committee was actively responsible for many structural alterations and new buildings, and he was especially interested in the successful completion of the Elphinstone Hall at King's College in commemoration of the founder.

He played an active part in the educational world of the North of Scotland, and was instrumental in the development of many institutions and projects.

His services during the war, first for the Ministry of Munitions, then for the Ministry of Labour, and finally as Chairman of the Inter-Departmental Committee on labour questions connected with building, were recognised by the award of the O.B.E.

He never married, and is survived by his only sister, Mrs. Watson.

J. A. C.

JAMES DUNCAN McNEILE, son of Lieut.-Colonel J. M. McNeile, R.E., was born at Beckenham, Kent, on 1879 April 29. From St. Lawrence, Ramsgate, he went up to Sidney Sussex College, Cambridge, with a mathematical scholarship, and graduated as a Wrangler in 1902. He shortly afterwards became Fereday Fellow of St. John's College, Oxford, but eventually entered the teaching profession. After appointments as mathematical master at King William's College, Isle of Man, and Gresham's School, Holt, he joined the staff of Wellington College, Berks, in 1909, where he served as House Master and Senior Mathematical Master until his retirement in 1934 April. Nine months after his retirement, on 1935 January 5, he collapsed and died while ski-ing in Switzerland.

Although always interested in astronomy, his main contribution to the science was not made until late in life. As a volunteer worker on the Oxford Astrographic Catalogue he wrote (in conjunction with F. A. Bellamy) a short paper on faint stars with large proper motions (*M.N.*, **76**, 538, 1916). Later he had charge of the 7-inch refractor at Wellington College, but it was not until he joined the British Astronomical Association in 1927 that an opportunity to devote his energies to astronomy in their most suitable form presented itself in the shape of the Association's Computing Section. About that time the Association embarked upon its share of the lunar occultation programme, in response to Prof. E. W. Brown's appeal for observations and reductions of occultations, following the publication of his *Tables of the Moon.*

The work of reducing occultations for most of the British Empire was organised as part of the work of the Computing Section under the superintendence of McNeile. It was in this capacity that he was able to make full use of his untiring energy and enthusiasm for computing; he rapidly and efficiently organised his small band of workers to the huge task, setting an example by doing almost every reduction once himself, and he soon had a definite programme to which he could work year by year. He continued this work until his death; only a few days before he left for Switzerland he corrected the proof sheets of the list of reductions for 1933. In 1934

October he was appointed Director of the Computing Section, to which position he was admirably suited by nature.

Astronomy surely owes him a debt for his valuable but unspectacular work in reducing occultations, but even more so for his achievement in 1929, when he designed and constructed a machine for predicting lunar occultations. For several years his machine was on loan to H.M. Nautical Almanac Office, and did valuable service in enabling the elements of occultations not visible from fixed observatories to be omitted from the *Nautical Almanac*, and in obtaining preliminary times; a copy of his machine, constructed professionally in metal, has made possible a great extension of occultation predictions, so that they now cover the majority of probable observing stations.

McNeile had many other interests and activities; he was very interested in and adept at carpentry and photography, while fishing and winter sports were his favourite pastimes. His profession gave him opportunities for foreign travel, of which he took full advantage. Although rather shy in a large company he could be a most entertaining companion; his keen appreciation of national characteristics and his intimate knowledge of many subjects made his conversation always interesting, often humorous, but never banal.

He was elected a Fellow of the Society on 1930 January 10.

D. H. S.

WILLIAM GRASETT THACKERAY, the eldest son of the Rev. Richard William Thackeray, Rector of the parish of Hunsdon, Hertfordshire, and second cousin of William Makepeace Thackeray, was born on 1853 September 4 and died on 1935 March 31.

He was educated at Bedford Grammar School, and after competitive examination by the Civil Service Commissioners was appointed to the staff of the Royal Observatory, Greenwich, on 1875 February 25, to fill the vacancy consequent on the resignation of Mr. James Glaisher.

During the next sixteen years he was for the greater part employed on observing with the Transit Circle and in the reduction of the observations. In 1891 he was relieved from this work, and till his retirement on 1919 September 4 he superintended the miscellaneous astronomical computations, including the preparation of the Annual Greenwich volume for press and the formation of the star catalogues from the observations. Cognate to that work many papers by himself alone or in collaboration with others appeared in the publications of the Royal Astronomical Society.

He married in 1884 a Mrs. Hoare and had a daughter and a son. His wife died in 1902, and two years later he lost his son. For the last six years of his life he lived with his daughter and son-in-law.

His colleagues remember him as a gentleman of original outlook who expressed his views with freedom and with quaint humour.

He was elected a Fellow of the Society on 1890 January 10, and resigned his Fellowship in 1928.

EDWIN BRANT FROST.—By the death of Edwin Brant Frost, which took place on 1935 May 14, the Society has lost a valued Associate, and many astronomers in various countries have lost an intimate friend. Frost, who was born on 1866 July 18 at Brattleboro, Vermont, was of old New England stock. He was a descendant of Edmund Frost who landed in Boston on 1635 October 2, having left Ipswich in order "to avoid the more savage oppression of England." E. B. Frost's father was Carleton Pennington Frost, who in 1871 was appointed a professor in the medical school of Dartmouth College, and who later became Dean of the School and a trustee of the College. It thus came about that his two sons received their education there.

E. B. Frost, the younger son, graduated in 1886 with honours in physics. He remained at Dartmouth for a short while doing graduate work and serving as an assistant in the department of chemistry. He subsequently studied at Princeton with Young, who was at that time engaged in writing his textbook on General Astronomy. Frost assisted in reading the proofs—an excellent way of taking a course in astronomy. Late in 1887 he returned to Dartmouth as instructor in physics. In 1890 he went to Europe for a two years' stay. The second year was spent at Potsdam, where H. C. Vogel had established an astrophysical observatory. Astrophysical work was then in its infancy and Vogel's enthusiasm infected his associates, who included Scheiner, Müller, Kempf, Wilsing, Hartmann, Ludendorff, Eberhard and Lohse. Frost's year at the Observatory must have been a continuous source of inspiration. At Vogel's suggestion, he studied the distribution of radiation over the Sun's disc by thermopile observations. In 1892 February, Nova Aurigæ was discovered by Anderson, and during the temporary illness of Scheiner it fell to Frost to photograph the spectrum of the Nova with a makeshift spectrograph attached to the Repsold astrographic refractor. With the same instrument he also photographed the spectra of stars with bright lines. His future career was at this time being moulded.

In 1892 Frost returned to Dartmouth as assistant professor and Director of the Observatory. He no doubt felt the loss of facilities for astrophysical research, but busied himself with the translation of Scheiner's *Spectralanalyse der Gestirne*. He, however, had to produce more than a mere translation. The subject was growing rapidly and new matter had to be incorporated with the original volume. The result of Frost's efforts was a work which until quite recently remained a standard textbook on astrophysics.

In 1896 Frost became professor at Dartmouth College, and in 1898 he was invited by G. E. Hale to join the staff of Yerkes as professor in astrophysics. He accepted the invitation, and to Yerkes he came. It was there that the major part of his work was destined to be done, and his connection with Yerkes was to last until his death. It is only possible here to mention briefly the more striking aspects of our Associate's activities. After the construction of the spectrograph attached to the 40-inch refractor, it was decided to concentrate on two types of stars—those of class B and class M. It fell to Frost to be responsible for the B-type programme, the M stars being attended to by Hale. From 1901 onwards W. S. Adams collaborated

with Frost, and in 1904 an important paper by Frost and Adams appeared entitled "Radial Velocities of Twenty Stars having Spectra of the Orion Type." This was one of four major papers. Another arose out of Frost's suggestion that radial velocity observers should prepare a list of standard velocity stars, with the object of checking systematic errors. Later, in conjunction with Barrett and Struve, Frost was responsible for a heavy programme of observation work on B- and A-type stars, and results for 368 of the former and 500 of the latter were published in 1926 and 1925 respectively. In addition to his major work, Frost was the author of many notes on individual stars.

In 1895 Frost had become an assistant editor of the *Astrophysical Journal*. In 1902 he became an editor and served for more than thirty years in that capacity.

But before the completion of the programme on the radial velocities of the stars of early type our Associate was struck down with what is perhaps the hardest affliction that an astronomer can undergo. In 1915 his left eye was affected by a detached retina. This was followed by cataract in the other eye, and as the years went on he would, with a wonderful cheerfulness and belittlement of his affliction, estimate the gradual diminution of the percentage of normal vision left to him. But he remained Director of Yerkes, to which post he had succeeded Hale in 1905, until 1932, when he became Director Emeritus. He once wrote: "With a good memory and an active imagination, one can see much without the use of eyes." P. Fox has related how he listened to the chirping of crickets, and derived the formula $y = ax + b$ where y is the temperature, x the number of chirps per minute, b the temperature at which the chirping stops, and a the constant number 13. S. A. Mitchell has remarked that whenever he gave a lecture illustrated by lantern slides, the presentation was so clear that it was difficult to realise that he could see neither the audience nor the screen.

Frost was a lover of music, of which he had a wide knowledge. The loss of his sight made his hearing even more acute. He was able to tell the number of every engine on the North-Western and St. Paul railroads by its whistle and he could give perfect imitations of the calls of different birds. If a former member of his staff arrived unexpectedly to revisit the Yerkes Observatory after a long interval, Frost would at once recognise the footstep and welcome him by name.

He was a lover of outdoor life, of nature in all its aspects, of the birds and the flowers. "As for me and mine, we like the open spaces with their sense of freedom, their beauty and their calm." The grounds at Yerkes were planted with trees and shrubs under his supervision, and he knew where each one was to be found.

Amongst children he was particularly happy, and it was typical of his love for them that when, a few years ago, serious illness necessitated his removal to hospital in Chicago, as soon as he was convalescent he went down to the children's ward and talked to them about the stars.

Frost married in 1896 Miss Mary E. Hazard, of Boston, who survives him with their three children, a son and two daughters. Their married life

was one of perfect understanding and mutual helpfulness, and their home was one in which their many friends were always welcomed with the most cordial hospitality. Frost was elected an Associate of the Society on 1908 June 12.

CHARLES EDWARD ST. JOHN.—Astronomers who had the privilege of knowing St. John held him in most affectionate regard. It seems natural to compare him with Barnard. They both had the same unaffected and simple manner, and kindly disposition. They had equal enthusiasm for astronomy and capacity for hard and careful work. Another resemblance was their love of nature and their knowledge of birds and trees. In his long and active life St. John enjoyed work and play and his capacity for friendship to the full. It may be truly said, "He warmed both hands before the fire of life."

His life of research, in which we are more particularly interested, did not begin till he was over fifty. Born at a small town Allen, in Michigan, on 1857 March 15, he graduated at the normal school at the age of nineteen. After ten years of poor health he became Instructor in Physics at the same school. At the age of thirty-five, after post-graduate work in Magnetism and Electricity, he obtained the degree of Master of Arts at Harvard, and the John Tyndall Fellowship which enabled him to spend a year at Heidelberg and Berlin. Here he was introduced to the study of black-body radiation. A year after his return to America he became Professor of Physics and Astronomy at Oberlin in Ohio. His pupil, Alfred H. Joy,* tells how he put the same energy and enthusiasm into his teaching which he afterwards showed in his astronomical work, and mentions other interests in the town and college to which he gave time and thought, and recalls the reputation for absent-mindedness which he acquired.

St. John spent the summer vacation of 1898 at the Yerkes Observatory on the invitation of Dr. Hale. This was repeated in several later years, and in 1900 he assisted Dr. E. F. Nicholls in his pioneering attempt to measure the heat of Arcturus with a radiometer.† In 1908 he resigned his post at Oberlin, and was appointed on the Staff of the Mount Wilson Observatory shortly after its inauguration. The first few years he lived on the Mountain in the "Monastery" in company with Abbot, Adams, Barnard, Ellerman, Gale and Kapteyn. He then moved to a bungalow in Pasadena, where he stayed till the end of his life.

St. John's main interest was in Solar Physics. With the large telescopes of the Mount Wilson Observatory he obtained excellent spectrograms of high dispersion. These he carefully measured by comparison with terrestrial lines. It was necessary to know the wave-lengths of these with all the precision possible. Abbot quotes three of his earliest papers as characteristic of his methods. Interferometer standards had recently been determined by Fabry and Buisson. Through the intermediary of iron lines he

* I am indebted to Abbot (*A.J.*, **82**, 274), Babcock (*P.A.S.P.*, **47**, 115), and Joy (*P.A.*, **43**, 611) for parts of this notice.

† Joy, *loc. cit.*

obtained the wave-lengths of the *H* and *K* lines of calcium with an accuracy of 0·001 A. He then found that the absorption line K_3 over the surface of the Sun had a descending motion of 1·14 km./sec., while the bright emission line K_2 had a mean ascending motion of 1·97 km./sec. In the same paper he finds that the angular velocity of the K_3 line is nearly constant for the latitudes of observation, being 15°·4 and 15°·5 per day in latitudes 6°·6 and 38°·4 respectively. In the third paper he deals with the motion of calcium vapour over sunspots and flocculi.

In 1913 he verified Evershed's discovery of the outward flow of matter in the penumbræ of sunspots. In 1915 he considered Julius's theory of anomalous dispersion, but concluded that it was of little importance in solar phenomena. He next investigated Einstein's prediction from the Generalized Theory of Relativity that the Fraunhofer lines would be displaced to the red owing to the effect of the Sun's gravitational field. He at first found a negative result from 40 lines in the band spectrum of cyanogen, choosing these lines on the ground that pressure shifts would be negligible. When it was realised that the pressure in the reversing layer was very small he repeated his work, measuring no less than 1537 lines, including a large number of Iron and Titanium lines and 515 lines of Cyanogen, and concluded that the shift to the red was in accordance with Einstein's theory.* Other researches were undertaken in co-operation with his colleagues at Mount Wilson. With Adams he worked on the rotation of the Sun and an attempt to find water-vapour and oxygen in Mars. He was associated with Babcock in several researches having the object of finding what small shifts might arise from pressure and the pole effect in the spectrum of the iron arc. In 1912, with Miss Wace, he investigated the errors in Rowland's Table of Solar Wave-lengths. In 1916 he came to the conclusion that the wave-lengths could not be transformed to the International system in any general way, but that an extensive and complete revision was required of a work which had been of the greatest value for twenty years.

Under the auspices of the International Union for Solar Research in 1907 and 1910 and later of the International Astronomical Union in 1922, a series of standards, mainly of Iron Arc lines, based on the wave-length of the red Cadmium line 6438·4696 A., was constructed free from cumulative errors. St. John and his colleagues at Mount Wilson determined the wave-lengths of the solar lines by comparison with two independent series of spectra, one taken by the 75-foot spectrograph of the Mount Wilson Observatory, the second by an interferometer. The wave-lengths from these two sources rarely differed by 0·002 A. The Revision of Rowland's Tables was completed after ten years' work and published under the names of St. John, Miss Moore, Miss Wace, Adams and Babcock. The work was much more than a revision. The intensities of the lines in spots were given along with those in the disc. The identification of the lines has been carried out with great thoroughness, and the behaviour of the lines in the elements to which they are attributed indicated by their classification in King's electric furnace. Ionized elements are marked, and excitation potential given when known.

* See Evershed, *M.N.*, 96, 152.

In an appendix the wave-lengths from λ 7537 to λ 10218 are added from measures of spectra at Mount Wilson.

In 1930, shortly after the publication of this great work, St. John retired from the staff of the Mount Wilson Observatory and was made Research Associate. He kept up an interest in his former work, though he was troubled by ill-health. This he bore philosophically, and was devotedly cared for by his cousin Mrs. Elvira Seeley. He died, after an attack of pneumonia, on 1935 April 26.

St. John took an active part in the Solar Union on the subject of Solar Wave-lengths at the meetings at Mount Wilson and Bonn and later in the International Astronomical Union. He was President of the Commission on Standards of Wave-lengths and Solar Spectra in 1932, and succeeded Dr. Hale in the Presidency of the Commission on Solar Physics in 1925, continuing in that office till 1932. He was a member of several American astronomical and kindred scientific societies, and was elected to the National Academy of Sciences in 1924. He was a member of the Société Astronomique de France. He was elected an Associate of the Royal Astronomical Society on 1917 June 8.

F. W. D.

PROCEEDINGS OF OBSERVATORIES

The following reports of the proceedings of observatories during the past year have been received from the respective Directors, who are alone responsible for them.

Royal Observatory, Greenwich
(*Director, Dr. H. Spencer Jones, F.R.S., Astronomer Royal*)

Transit Circle.—The number of transits observed during 1935 was 9711, including 119 of the Sun and 101 of the Moon. Work on the Zone Catalogue of Stars between the equator and declination +24° is proceeding steadily. The observing programme now includes observations of the brighter minor planets, and during the year 12 transits of Juno and 20 of Vesta were observed. The purpose of these observations is to investigate the question of systematic error in the absolute system of declinations obtained with the instrument.

The *Second Greenwich Catalogue of Stars* for 1925·0 has been issued.

The position for 1935·0 of Nova Herculis 1934, as obtained from six transit circle observations, is R.A. $18^h\ 5^m\ 39^s{\cdot}85$: Dec. $+45^\circ\ 50'\ 54''{\cdot}2$ (Epoch 1934·99).

Cookson Floating Zenith Telescope.—The monthly numbers of plates taken for the determination of the variation of latitude were :

January—10	May—23	September—36
February—6	June—31	October—36
March—36	July—39	November—21
April—30	August—34	December—9

In addition to these, three plates were taken for the determination of scale.

A new brick building is being constructed to house the instrument. It is situated in the Christie Enclosure, next to the South Collimator House of the reversible transit circle.

The programme of observations with the Cookson telescope at Greenwich was originally planned for the determination of the constant of aberration, as well as of the latitude variation. In the winter months, observations are made both evening and morning in order to obtain large aberration factors. In a paper published in the *Monthly Notices* for 1935 December, some of the results have been discussed. It appears that corrections to the adopted constant of aberration obtained in this manner are vitiated by systematic error arising from meteorological causes.

When the instrument is moved to its new position, the present programme will be terminated and a new one, planned for the determination of latitude variation only, will be commenced. 24 groups, generally comprising 5 or

6 pairs of stars, and each extending over about 1 hour in right ascension, have been selected. Three groups centred round midnight will be observed throughout the year.

The stars for the new programme are being observed with the Transit Circle.

28-*inch Equatorial.*—Occasional observations have been made with this instrument, and 106 measures of 87 double stars were secured during 1935.

26-*inch Refractor.*—The number of plates taken suitable for the determination of stellar parallax was 439. 1140 plates were measured and 44 parallaxes completed. The parallaxes of 40 stars were published in the *Monthly Notices* for November. 16 plates were taken through the glass for the determination of proper motions of parallax stars with an interval of ten years or more. 5 plates for this purpose have been measured.

The instrument was out of use between June 17 and October 21 while alterations were in progress. In order to permit of the addition of a dewcap, a section, two feet long, was removed from the upper part of the tube and a corresponding extension added to the breech end. A sliding dewcap has been installed which protects the object-glass from dew on quiet moist nights, but which can be withdrawn on gusty nights. Forced ventilation of the tube by a fan is now available. This reconstruction has necessitated the removal of the false floor in the dome, and this has led to greater floor space and enhanced convenience. The 9-inch photoheliograph has been transferred and is now mounted on the 30-inch reflector.

In addition, the drive has been modernized by the installation of a synchronous motor, which has given satisfactory performance. The transmission system has been overhauled.

Yapp 36-*inch Reflector.*—The programme of colour temperature work with the slitless spectrograph has been continued. 233 comparisons of 91 stars of spectral type O – Go with standard stars have been secured. One-third of these have been measured.

42 plates have been exposed on Nova Herculis 1934, including 16 plates taken in 1934 December. These have been calibrated for photometry, and whenever possible a comparison star was photographed at approximately the same altitude. A selection of these plates has been measured in the regions near $H\alpha$, $H\beta$, $H\gamma$ and $H\delta$. Observations of the comparison stars against Greenwich standard stars have been secured and measured.

40 plates, 14 of which were secured in 1934, have been taken for the purpose of standardising the calibration of plates taken with the 36-inch reflector. In these plates the method of full and half apertures on the telescope was employed. A brief résumé of the results has been published in *The Observatory* for 1936 January, and a further reference to the work will appear in the forthcoming transactions of the Paris Meeting of the International Astronomical Union.

The two secondary mirrors of the reflector and the mirrors of the slitless spectrograph have recently been aluminized by Messrs. Metropolitan Vickers Ltd.

The construction of the new slit spectrograph by Messrs. Adam Hilger Ltd. is proceeding.

Astrographic Equatorial.—49 plates have been exposed on the minor planet Hebe. These were taken between September 14 and December 31. It is intended to secure a set of photographs extending 4 months before and after opposition. These will yield corrections to the elements of the planet's orbit and of the orbit of the Earth.

17 photographs of the planet Eros, taken for the purpose of correcting the orbit, have been taken between October 4 and November 13.

Photoheliograph.—The Sun was photographed on 288 days at Greenwich, and on 347 days at the Cape. Two days are not represented by either series, but plates for these dates are available at Kodaikanal.

For 1935 the mean daily area of sunspots, corrected for foreshortening, was approximately 550 millionths of the Sun's hemisphere. The published values for the years 1925–34 are 830, 1262, 1058, 1390, 1242, 516, 275, 163, 88 and 119 respectively. The usual summary of positions and areas of sunspots for the year 1934 was published in *Monthly Notices*, **95**, 761, 1935. Sunspot numbers have been supplied quarterly to Zurich for incorporation in the *Bulletin*.

The work of copying on bromide paper the series of solar negatives at Greenwich from 1874 to 1903 has been completed, and the prints are stored in cases contained in a steel press.

Spectrohelioscope.—Observations were made in $H\alpha$ light on 178 days, and include measures of radial velocity of 382 dark flocculi associated with sunspots and 269 measures of dark flocculi not associated with sunspots; 113 measures were also made on areas of bright flocculi. During the year 25 bright eruptions, mostly of minor extent, were observed in $H\alpha$ light on the disc, and these have been reported to Meudon. A paper drawing attention to two allied types of chromospheric eruptions was published in *Monthly Notices*, **95**, 650, 1935.

On days when conditions were favourable, measures of intensity of bright flocculi and prominences were made with the photometer that was attached to the spectrohelioscope in 1934. Measures of 50 flocculi and 62 prominences seen in $H\alpha$ light and measures of 10 prominences in $H\beta$ light were made during the year. A number of observations were made on four days to determine the profile of $H\alpha$; in addition, observations by the half-aperture method were made on eight days to check the maker's calibration of the wedge used in the photometer. The intensity measures made at Greenwich during 1934 and 1935 are discussed in a paper published in *Monthly Notices*, **96**, 5, 1935. Of special interest is the ratio of the intensities $H\beta/H\alpha$ determined from 22 prominences, the mean value being 0·26 for the ratio of the maximum intensities (*not* the total intensities).

Measurement of Total Line Intensities in the Solar Spectrum.—These experiments, to which reference was made in the last report, are now being carried out in the basement of the 36-inch reflector dome. A cœlostat and secondary mirror have been mounted on brick pillars standing on a concrete base. These instruments are protected from the elements by a light hut,

constructed in the workshop, which can be run away on rails, admitting sunlight to the cœlostat. The beam enters the basement through a window. The solar spectrum is formed by a 4-inch concave grating spectrograph, and is made to fall on a second slit. The short length of spectrum which passes through the second slit is then further dispersed by a single prism mounted in the Littrow form, which separates out the true spectrum from scattered light which has fallen on the second slit. It is intended to make measurements by photography, with the thermocouple purchased in 1934, and with the eye, using the method of an auxiliary lamp, as used at present in the spectrohelioscope observations.

Investigation of the Performance of a Grating.—An investigation was made of the amount of light scattered into the centre of an artificial absorption line by the 4-inch concave grating spectrograph. Light from a "Pointolite" lamp was dispersed by a large prism and the spectrum was brought to a focus, at which the dispersion was 60 A./mm. in the yellow. The light was then reflected back to the original prism, which re-combined the rays to form a white image, unless an obstruction had been made at the spectrum focus. A thin wire placed at the focus produced an artificial absorption line in the light, which was otherwise white. When this light was examined with the grating spectrograph the artificial absorption line was seen, but had a non-zero central intensity. The false central intensity of a narrow line was 5 per cent. of the intensity of the continuous spectrum. On examining the image of a bright region of the spectrum about 5 A. in width, it was seen that the false light was concentrated for the most part into definite maxima or ghosts. The principal pair of ghosts have an intensity of 1 per cent. of the main line, and are situated at a distance of 26 A. from either side of it. The scattered light was seen to come from groups of defective rulings on the grating. According to Allen (1903), the bad rulings are sets of rulings spaced a little too closely or a little too far apart.

These investigations show that the grating is not suitable for line intensity work, and a train of four prisms has been ordered to replace it. They are being constructed by Messrs. Ross Ltd.

Clocks and Time Service.—The clock corrections for 1935 have been based on observations made between sunset and midnight on 113 days with the small reversible transit. In addition, observations were made on 4 occasions, shortly before dawn, for the purpose of detecting a suggested variation in observed clock correction due to a lunar effect. The transit observations are recorded on a tape chronograph operated by a thermionic valve system.

The Free Pendulum clock Shortt No. 3 has been used as Standard sidereal clock throughout the year.

F.P. clock Shortt No. 11 was dismounted on January 18 for overhaul, after a run of $8\frac{1}{2}$ years, and was reassembled in February.

The mean-time F.P. clock Shortt No. 16 controlled all mean-time signal distribution, including radio time-signals from Rugby and B.B.C. stations and the hourly telegraphic time-signals to the General Post Office from January 1–February 14, and again from October 29 to December 31.

The mean-time F.P. clock Shortt No. 49 controlled the above services from February 14–October 29.

F.P. clock Shortt No. 16 was dismounted on February 20 for overhaul, and was re-erected at the end of March in the cellar adjoining that containing the sidereal F.P. clocks.

With the exception of periods of overhaul and adjustment, regular comparisons have been maintained between the Standard sidereal clock and the reserve sidereal and mean-time Standard clocks.

Daily registration has been made of radio time-signals from Rugby and Bordeaux throughout the year, and from Nauen until March 12.

A cathode ray oscillograph apparatus, including a motor-driven cine-camera and time base marker, has been used at intervals for determination of the lag of the recorder used for radio time-signals.

A generous offer to present to the observatory a free-pendulum installation has been made by Mr. H. R. Fry, F.R.A.S., and has been accepted by the Admiralty. The two sidereal free-pendulum clocks which the observatory at present possesses are required for routine purposes. One is used as the standard clock ; the second is kept available for adoption as standard whenever it may be required. The new clock will not be required for routine work, but will be available for experimental purposes, though it will also serve to improve the accuracy of the time distributed from the observatory. The need for a third sidereal clock of this nature has often been felt. The new installation will include an improved slave clock, and time will be taken directly off the free pendulum by a photo-electric method. The construction of the new clock is well advanced.

Observations of Eros.—The measurement and reduction of the plates taken in connection with the 1930–31 opposition is proceeding. In addition to the series (*a*) to (*h*) listed in last year's report, the following additional series of plates have been received from the Union Observatory, Johannesburg:

(*j*) A series of 89 plates exposed on Eros near the meridian with the Cooke 10-inch telescope of 92 inches focal length.

(*k*) A series of 88 plates exposed, with the same instrument, on Eros, near the meridian and at large hour angles, using orthochromatic plates and a yellow screen.

During the year 280 plates of series (*g*), 24 of series (*h*) and 27 of series (*j*) were measured.

The reductions are in hand. As regards series (*a*) and (*b*) the work is approaching completion. These series consist of plates taken with the Greenwich and Cape astrographic telescopes for the purpose of obtaining positions of secondary comparison stars required for the reduction of Eros plates obtained with long focus instruments. The conversion of measured co-ordinates into R.A. and Dec. is complete for the 690 stars south of declination $-14°$ and is proceeding for the stars between $0°$ and $-14°$.

Air Pollution.—Apparatus for measuring the amount of sulphur dioxide present in the air, and for estimating the amount of solid pollution, has been in operation throughout the year. As would be expected, the amount of

pollution of both kinds is greatest on days of fog and, generally speaking, is least when the wind is strong from a southerly direction.

The worst month in the year for gaseous pollution was January, when sulphur dioxide was present in the proportion of 0·146 parts per million on an average. The worst days were almost double as bad as the average. A steady decrease in the monthly mean went on until the minimum of 0·016 parts per million was reached in June. The increase during the remainder of the year was comparatively small until November. The mean for December was 0·076 parts per million.

A general parallel to these results is shown by the figures for pollution by solid matter as given by the Owens automatic air-filter. *E.g.* solid pollution also reached its maximum in January. The mean weight of suspended impurity during that month was 146 milligrams per 100 cubic metres of air.

The figures taken as a whole show that during the winter months pollution of the air by suspended matter is fully as great at Greenwich as at any station making these measures in Britain (these stations being all in industrial areas), although in central Glasgow the pollution is worse at the worst times of the day.

New Reversible Transit Circle.—In the last report it was stated that this instrument had been completed by Messrs. Cooke, Troughton and Simms, and was undergoing final tests in York. As a result of these tests, modifications to the counterpoise system were found to be necessary. These modifications have been effected, and the work of erection at Greenwich was commenced on 1936 February 4.

Printing.—The volume and separate parts of *Greenwich Observations*, 1933, vol. ii of *Observations of Stellar Parallax* and the *Second Greenwich Catalogue of Stars* for 1925·0 have been distributed. The final proofs of *Greenwich Observations* for 1934 have peen passed for press.

Miscellaneous.—The original manuscript of Flamsteed's observations has been presented to the observatory by the Radcliffe Trustees. The Trustees have also presented a manuscript volume of observations made by Bliss at Oxford during his tenure of office as Astronomer Royal.

The optical grinding machine constructed by the late H. G. Tomkins of East House, Dedham, near Colchester, has been presented to the observatory by Mrs. Tomkins.

Mr. R. H. Stoy studied the work of the observatory during the latter half of September prior to taking up his appointment as Chief Assistant at the Cape Observatory.

Mr. H. G. S. Barrett of the Radcliffe Observatory is working at the observatory, his services having been lent by the Radcliffe Trustees. He is assisting in the reduction of the Eros plates.

Royal Observatory, Edinburgh

(*Director, Professor R. A. Sampson, F.R.S., Astronomer Royal for Scotland*)

For the most part work has continued upon the same lines. In the case of the Great Reflector in the East Dome, Nova Herculis 1934 occupied most

attention. A total of 88 plates have been taken of this star altogether, of which 64 were taken in the course of 1935. Some of these were taken with the two-prism (glass) system, some with the one-prism (glass) system, some with the one-prism (quartz) system. A portion of the negatives have been sent to Prof. Stratton, to fill up gaps in the Cambridge series, or for other purposes connected with the resolution of the International Astronomical Union. In view of the uncertain weather here some regard is paid to the time when the exposure may be expected to be completed. Also the spectrum must be sufficiently broad to submit to the photometer. It is found that about 4·5 magnitude is a fair average that can be reached, though, if necessary, a considerably fainter magnitude could be recorded. A Dekkor viewer, by A. Hilger Ltd., has been acquired for preliminary survey of enlarged images of spectrograms.

In the West Dome most of the work has been done with the 10-inch camera. The programme is to search for variables in the selected areas 2 to 19. The pairs of plates taken with the camera are then examined with the blink microscope. A considerable number of variables have been found, in addition to those catalogued, and others await verification.

In the chronometric system the wireless receiving apparatus was now badly out of date, though it was constructed only eight years ago. After some enquiries a new set was made in the observatory workshops, as this seemed much the most economical and satisfactory plan. Mr. E. A. Baker, to whom we owe the design, describes it as a mains-fed receiver, consisting of a high-frequency amplifier with three tuned circuits, a triode-hexode frequency changer, and a low-frequency amplifier with two low loss tuned circuits. The present coils cover a wave band from 10,000 to 20,000 metres, and therefore include all the long-wave emissions of wireless signals. Good results are obtained from the European stations. The reconstruction of the Annapolis station renders the tests incomplete, but judging from a substitute American station—WCI—when Annapolis resumes sending reception ought to be without interference.

The case of Shortt No. 0 has held throughout the year. On the other hand that of Shortt No. 4, which was reported as correct last year, sprang a small leak in December, the origin of which has not yet been discovered.

Royal Observatory, Cape of Good Hope
(*Director, Dr. J. Jackson, H.M. Astronomer*)

Reversible Transit-Circle.—The observation of stars between the equator and declination $-30°$ is nearly completed. The working list contains 7415 stars down to magnitude 7·5, with fainter stars in sparse regions. The number of transits observed during the year was 8275, including 211 of the Sun, 86 of Mercury and 154 of Venus. The exterior planets, including Vesta, have been observed during the usual evening hours of observation.

This programme should be completed early in 1936, and it is then proposed to undertake the observation of southern circumpolar stars at

both culminations during the winter months. There has been no fundamental determination of the positions of these stars since 1917.

The observations of stars south of declination $-30°$ made in the years 1925 to 1932 have been reduced to 1925·0. The differences depending on the position of the instrument agree closely with those found previously. The correction to the adopted latitude of $-33°\ 56'\ 2''{\cdot}50$ is $-0''{\cdot}03$. A comparison of the clock corrections derived from day and night observations shows very nearly the same periodic corrections to Boss's Catalogue as were found from observations twenty years earlier.

Eight-inch Transit-Circle.—This instrument has been used for the determination of the positions of stars required for the reduction of plates taken with the wide-angle lens in the zone $-35°$ to $-40°$. The Boss stars which are too bright for accurate measurement on the photographs are also being observed. During the year 2303 transits, including those of 85 polar stars, were observed.

Photographic Zone Observations.—(*a*) Zone $-30°$ to $-35°$. Forty-one plates to R.A. 8 hours were completely measured. The total number of stars, each of which has been measured on two overlapping plates, is just over 4000. The stars measured have been selected from the Cordoba Catalogues B and C, brought forward to the epoch 1950·0. The standard co-ordinates for these stars have been computed ahead of measurement so as to avoid the risk of measuring the wrong stars. In regions where the Cordoba Catalogues contain a very large number of stars the fainter stars are being eliminated.

(*b*) Zone $-35°$ to $-40°$. After the return of the wide-angle lens from the makers it was tested by out-of-focus plates and found satisfactory. The component lenses had been readjusted, and a stop had been introduced. The regular work of photographing this zone was commenced in May, and it is hoped that it will be completed in one year. Up to the end of the year 109 plates had been obtained.

Cape Astrographic Zones $-40°$ to $-52°$.—The copy for press of the Catalogue, giving the proper motions of the 20,843 stars in the Zone Catalogue for 1900, was completed and sent to the printers. The proofs of the tabular matter have been received and more than half checked.

The most interesting result which was obtained from the discussion of the proper motions was in connection with star streaming. It was found that there was no dependence of the position of the vertex on spectral type, although the distribution of stars in the zone was quite different for stars of different types, early type stars being confined to the neighbourhood of the galaxy. On the other hand, the position of the vertex derived from stars of all spectral types varied with the galactic latitude, the right ascension of the vertex being about 10° less for stars near the galaxy than for stars in high galactic latitude.

The copy for press of the Catalogue of 20,554 stars, fainter than 9·0 magnitude according to the C.P.D., was completed as far as the positions, precession, proper motions and magnitudes are concerned. The spectral types for about one-quarter of the stars are available from the Henry Draper

Catalogue. Although the stars in this catalogue are of the same C.P.D. magnitude for all parts of the zone, actually the stars are brighter in the rich regions of the Milky Way than in high galactic latitudes. A large proportion of the stars in the rich regions are of early spectral type. Dr. Shapley has kindly offered to supply spectral types as far as possible from the Harvard plates, and the manuscript for several hours of R.A. has been sent to him. The identification of the stars on the Harvard plates is rather laborious, but the work is being carried on under Miss Cannon's supervision. The publication of the catalogue will be delayed for some time to enable this work to be done, but the importance of the spectral types warrants this delay.

Victoria Telescope.—The instrument was in use on 249 nights on work connected with the determination of stellar parallax. 2341 plates were obtained for the regular programme and 84 for determination of the proper motion in declination of stars for which the parallax has already been published. One focus plate was taken.

2341 plates were measured for parallax, and 183 were rejected as unsuitable for measurement, principally on account of poor atmospheric conditions when the plates were exposed. There are in hand, awaiting measurement, 975 plates.

A seventh list of parallaxes, bringing the total to 650, was published in the *Monthly Notices* for November. The parallax of only two stars exceeds $0''\cdot100$, viz. B.D. -5° 1844, and B.D. -3° 4233, for which the determinations are $+0''\cdot136 \pm ''\cdot010$ and $+0''\cdot129 \pm ''\cdot006$, respectively. The second of these is the first determination for this star. The detailed results for the first 217 stars for which the parallax has been determined were published in *Cape Annals*, vol. xiv, part 1.

Opposition of Eros 1931.—The reduction of the photographs has been carried forward as far as obtaining residuals between the measured and the ephemeris positions of the planet. The correction to the R.A. of the ephemeris decreased gradually from about $+0^s\cdot07$ at the beginning of 1931 to about $-0^s\cdot07$ in the middle of February, at which value it remained nearly stationary till the end of March, after which it increased again to $-0^s\cdot04$ at the end of April. In declination the correction was about $-2''\cdot0$ at the beginning of the year, it increased to about $+0''\cdot4$ early in March and then decreased again to $-0''\cdot2$ at the end of April.

The actual derivation of the solar parallax is held over till more accurate places of the reference stars are available.

Heliometer.—The use of the heliometer for the observation of the major planets near the times of opposition has been discontinued. The observation of these planets is now carried out with the reversible transit-circle during the normal hours of observing.

Occultations.—The following occultations of stars by the Moon were observed :—

Disappearances at the dark limb .	32
Reappearances ,, ,, ,, .	28
Disappearances ,, bright ,, .	4
Total	64

The star 17 G Libræ, for which the occultation had been observed to take place in two stages, has been observed as a double star at the Union Observatory, Johannesburg.

The observations made in 1932, 1933 and 1934 have been reduced and those made in 1935 are in hand.

Photoheliograph.—694 photographs of the Sun were secured on 347 days. In addition 26 plates were taken for the determination of zero position angle. Visual observations for this purpose were made weekly.

Original negatives up to 1935 October 8 and duplicates up to 1935 September 16 have been sent to Greenwich for measurement and preservation.

Clocks and Time-Service.—The Sidereal Clock Shortt 10 ran well throughout the year. The case was opened for alteration of rate in July, when Riefler 152 was substituted as standard. The second Riefler Clock No. 150 developed a slow leak in the case in July, and this has not yet been located.

The Mean Time Clock Shortt 27 has again given some trouble, and it has been out of action since September 23. Since then its place has been taken by Dent 2004. All the other principal clocks have functioned satisfactorily.

Time-signals are transmitted through the post office at each hour of Greenwich Mean Time, for general distribution. A gun is fired from Signal Hill at noon, South African Standard Time. A time-signal consisting of six dots is sent by the Molyneux Clock to the African Broadcasting Company at 1 p.m. and hourly from 5 p.m. to 9 p.m. For use at sea a time-signal of the modified ONOGO type is emitted at 21 hours U.T. (23 hours South African Standard Time) on a wave-length of 625 metres *via* the Slangkop Wireless Station. The emissions are made by a Belin emitter, released and controlled by a half-second Leroy clock, which in turn is synchronised by the standard mean time clock. In case of failure this signal can be replaced by the six dots used in broadcasting—the real time-signal sent out by the Belin emitter consisting of six dots at the end of three consecutive minutes.

The time-signals sent out at 8 hours from Bordeaux and 10 hours from Rugby are each observed about twice a week.

New Instruments.—The two new lenses of 5-inch aperture and 35-inch focal length, the one corrected for photographic and the other for visual light, have been temporarily mounted on the 6-inch equatorial. Some trial plates have been taken, which show that the visual lens covers a field 15° in diameter very well, while the photographic lens covers the field not so well. A new building with a sliding roof has been erected to house these lenses, but the clockwork of the equatorial, originally made for visual observations, is not accurate enough for long exposures.

Staff.—Dr. R. H. Stoy has been appointed Chief Assistant, and he arrived at the Cape on November 15.

Armagh Observatory
(*Director, Rev. W. F. A. Ellison*)

The 6-inch equatorial was in use chiefly for observations of the Sun and Moon, for which it was designed by the Director; also, on occasions for demonstrations of objects of interest to visitors when the weather was favourable. The object-glass is excellent also for such planets and double stars as its moderate aperture can deal with.

The 10-inch equatorial deals more effectively with planetary detail, and this instrument was used during the Opposition of Mars in April to obtain drawings of the planet. Unfortunately weather was none too favourable, but some good views were obtained, especially of the Mare Acidalium region. Jupiter in May was rather low for good seeing. Saturn in August–September was much better. The focal length of the 10-inch objective is rather short for the best planetary definition; the 6-inch is much better in this respect.

The 18-inch reflector has been out of use for a great part of the year, owing to repairs to the roof of the dome. These have been much hindered by weather, and are not yet complete.

Cambridge Observatory
(*Director, Sir A. S. Eddington, F.R.S.*)

The new photographic object-glass for the Sheepshanks telescope was delivered in June. The mirror (at the Coudé joint) has been aluminised. The regular programme of photo-electric observation of variable stars was recommenced after these changes on September 19; but the weather has been very unfavourable for photometry, and it is as yet difficult to judge how much advantage has been gained. The following stars were under observation between September 19 and December 31: β Lyræ, *u* Herculis, *o* Herculis, β Persei, ϕ Persei, *b* Persei, ρ Cassiopeiæ, 1 H Cassiopeiæ, δ Cephei, λ Tauri, 55 Cygni, β Aurigæ, ζ Geminorum, Boss 5565.

The light-curves of δ Cephei and β Lyræ obtained from the observations in 1933 and 1934 have been published by Dr. Smart (*M.N.*, **95**, 644). It is noteworthy that, whereas the light-curve of δ Cephei repeats itself with great accuracy each period, irregular deviations in the light-curve of β Lyræ are conspicuously shown.

Thirty-nine plates of Nova Herculis were taken with a calcite prism spectrograph mounted on the Thorrowgood telescope, the majority by Mr. Green. Mr. Green has reduced and measured the wave-lengths from 3000 A. to 3800 A. on the best plate, taken on February 26 (*M.N.*, **95**, 694).

Mr. C. G. Pendse, Mr. R. A. Lyttleton and Mr S. W. Shiveshwarkar have been engaged in research under Dr. Smart's supervision, and Mr. M. Krook under the supervision of the Director. A theoretical investigation by Mr. Shiveshwarkar on the divergence between the direction of star-streaming and the direction of the galactic centre has been published; also

a paper on the radial velocities of clusters and nebulæ (*M.N.*, **95**, 655, 555).

Dr. Smart has published a paper on the "Mean Stellar Parallaxes derived from Proper Motions" (*M.N.*, **96**, 132). The Director has been working on the problem of the validity of the usual formula for the pressure of a degenerate gas, which is important in the theory of white dwarf stars. He has concluded that the so-called "relativistic" formula is not justified by relativity theory, and that the earlier formula $P = K\sigma^{\frac{5}{3}}$ is correct. The same rectification of the theory made possible further progress with the theoretical calculation of the cosmical constant (*Proc. Roy. Soc.*, **152**, 253).

Solar Physics Observatory, Cambridge University
(Director, Professor F. J. M. Stratton)

The staff remains unchanged. Mr. Shirley of the Radcliffe Observatory has been working as an additional member of the staff since the Radcliffe Observatory was closed for moving to South Africa. Mr. E. G. Williams has continued his work on the spectrophotometry of the B stars and Novæ ; Dr. A. Beer has been examining the spectrum of Nova Herculis 1934 at various stages of its life-history, and has continued to work at spectroscopic binaries. Dr. C. W. Allen has been studying the photometry of the Fraunhofer spectrum ; Dr. A. K. Das examined the cosmic radiation in connection with Nova Herculis and also worked at the spectrophotometry of the equatorial and polar regions of the Sun ; Mr. M. Krook, Research Student, has commenced working on the photometry of the metallic lines in the spectrum of Nova Herculis ; Major Noto, of the Japanese Meteorological Service, has been working on atmospheric electricity. Work on the ionosphere has been continued by Mr. J. A. Ratcliffe and other members of the Cavendish Laboratory, while Professor C. T. R. Wilson and Mr. J. G. Wilson have continued studying new methods of cloud chamber research at the observatory. Major R. A. Bagnold, Royal Signals, has been helping with the preparations for the solar eclipse expedition in 1936.

Buildings and Instruments.—The observatory has received as a gift from Captain W. N. McClean the solar spectrograph with which his father's work on the High and Low Sun was carried out (*M.N.*, **51**, 13, 1890). The observatory already has the original spectrograms obtained with the instrument. The 3-foot Common mirror has been refigured by Mr. C. R. Burch, Leverhulme Research Fellow, working at the Imperial College of Science, using a new method of testing developed by him (*M.N.*, **95**, 548, 1935). The astigmatism in the mirror, about 2 wave-lengths in amount, has been practically removed ; when the mirror was replaced in the telescope a definite astigmatism was observed, and this was traced to curvature in the 10-inch flat secondary mirror, a defect which only became noticeable after the performance of the 3-foot mirror had been so greatly improved. Mr. Burch is now kindly refiguring the flat.

Considerable work has been done in building up instruments for the eclipse expedition, the chief new item under construction being a two-prism

spectrograph with an automatic camera back for intermittent exposures on the flash spectrum. A thermostat and temperature case have been installed on the McClean-Littrow spectrograph, and a motor on the McClean cœlostat to control the run of the solar image across the thermocouple in the work on radiation from sunspots. A refrigerator for keeping photographic plates has been added to the dark-room equipment.

No major work on buildings has been carried out.

Solar Work.—Spectroheliograms were secured in K_{232} light of the disc on 98 days and of the limb on 88 days, in $H\alpha$ light of the disc on 50 days and of the limb on 43 days. The spectrohelioscope has been in regular use. A camera is being installed for use with the spectrohelioscope, so as to record variations in the solar markings dependent on small changes of wave-length.

Observations of total radiation from sunspots and surrounding faculæ have been continued. The largest spot measured showed an intensity in the middle of 0·32 of that of the surrounding photosphere, corresponding to an effective temperature of 4460°. Excess radiation from the faculæ is in general only a few per cent. of that of the photosphere, but one facula 1′ from the limb showed an excess radiation of 10 per cent.

Laboratory intensities of multiplets in the iron arc have been compared with corresponding intensities in absorption in the Fraunhofer spectrum.

With the McClean spectrograph and a monochromator a value of 2 per cent. has been obtained for the central intensity of the calcium line *g* at 4227.

In photometry of the Fraunhofer spectrum the following problems are being studied :—

(*a*) The actual intensities of selected lines in the region 5900–6300 A.

(*b*) The equivalent breadths of all available lines in the infra-red, 6600–11,000 A.

Stellar Work.—The Newall telescope has been devoted to a study of the spectral changes in Nova Herculis : 288 spectra were obtained on 193 nights, making a total of 340 plates on 209 nights since the discovery of the Nova. In addition 112 plates were secured on the Huggins 15-inch reflector by Dr. Beer, while 36 plates were taken by Mr. H. E. Green with a calcite slitless spectrograph mounted on the Thorrowgood refractor of the University Observatory. Several preliminary papers on the light curve, the visual spectrum and the interstellar lines have been published in the *Monthly Notices* ; other investigations are in hand on the radial velocities of the different absorption spectra, the spectral changes and the contours and intensities of the spectral lines.

The 3-foot reflector was out of action for some months owing to the absence of the mirror for refiguring. Work was done with it on 36 moonless nights : 31 plates were obtained in the programme on extra-galactic nebulæ. A new method essentially due to Professor Fabry is being tried for the determination of stellar magnitudes.

The photometric measures made on spectra of U Cephei and U Sagittæ (obtained by Dr. Redman at the Victoria Observatory in 1934) are nearly completed. The behaviour of the hydrogen lines $H\beta$, $H\gamma$, $H\delta$ in U Cephei

suggests that they vanish at the limb of the primary. In U Sagittæ the diminution in intensity from centre to limb is less marked though definitely present.

An attempt to determine the diameter of Antares by examining photographically its change in brightness while being occulted, was spoilt by a breakdown in the apparatus at a critical moment. The method appears to be workable.

Meteorological Physics.—Major Noto has been using the atmospheric electricity hut for continuous records of the atmospheric potential gradient, the sign and magnitude of the change carried by raindrops and of rainfall: he is studying the general electric phenomena accompanying electrically disturbed weather.

Night sky observations are being made with one of Lord Rayleigh's night-sky photometers whenever stellar observations are being made.

Laboratory Work.—Papers have been published on the electron configurations and term values in the spectrum of *Fe*II (*Proc. R.S.*, **157**, A, 703, 1935) and on new identifications of *Fe*II lines in the solar spectrum. The work on the lines enhanced at the pole of the iron arc is now being prepared for publication.

Dunsink Observatory
(*Acting Director, Mr. Charles Martin, M.A.*)

The time-service to Dublin has been continued as in previous years.

The observatory has been used mainly for teaching purposes, students being welcomed for instrumental instruction and observational work.

Imperial College Observatory
(*Director, Assistant-Professor H. Dingle*)

The two refractors and the transit instrument of the Observatory have been used mainly for the instruction of students as in previous years. An exceptionally large number of students have attended the course.

Research on many problems concerned with the analysis of atomic and molecular spectra has been continued in the spectroscopic laboratory and further interferometric determinations of wave-length standards have been made.

A new Eagle-type mounting for the 20-foot concave grating has been constructed in the College workshops and installed in the main laboratory. A new slit which is being made for it is not yet complete.

Liverpool Observatory and Tidal Institute
(*Director, Professor J. Proudman, F.R.S. ; Associate-Director, Dr. A. T. Doodson, F.R.S.*)

Tidal predictions of high and low water have been made for seventy-one places, of hourly heights of water for one place, and of times of slack

water for three places. Tidal observations from seven places (a total of twelve years' records in all) have been analysed.

Further research has been carried out on the analysis and prediction of tides in estuaries, in connection with Portsmouth, Avonmouth and Basra; also on the dynamical theory of tides in oceans bounded by meridians. Much work has been done on the collection of monthly and yearly mean values of sea-level observed at stations distributed over the world. The study of the variations of temperature of the surface waters of the Irish Sea has been continued.

An electrically recording current-meter of new design has been constructed for use in the Irish Sea, and a new Mercedes Euklid electrically operated calculating machine has been purchased.

Both telescopes have been repaired, cleaned and painted, and are now in good condition.

The regular meteorological and seismological services have been continued, but only weekly, monthly and annual climatological summaries are now sent to the Meteorological Office. The daily firing of the time-gun has been continued.

University of London Observatory, Mill Hill, and University College Observatory

(Director, Prof. L. N. G. Filon, C.B.E., F.R.S. ; Mr. C. C. L. Gregory, M.A., Wilson Observer)

Observations were made on 222 days. The Sun was observed with the 8-inch Fry telescope on 149 days, on 80 of which no night observations were possible ; observations were made on 142 nights. 21 observations of the magnitude of Nova Herculis 1934 were obtained, 35 successfully observed occultations, and 29 unsuccessfully attempted. 62 plates were obtained during the year, 5 proper motion plates of Wilson regions with the 24-inch reflector, 32 spectrum plates, mostly with a new 5-prism spectrograph by M. Tremblot, purchased during the summer for use with this telescope, of which 16 plates were for the purpose of testing the instrument, 8 for radial velocity determinations, and 8 spectra of γ Cassiopeiæ. 11 plates were taken with an experimental transitgraph, designed and constructed by Dr. Souttar and the Wilson Observer. Other plates were mostly taken with a portrait-lens camera attached to the 8-inch refractor, mostly by Mr. Frank Robbins. The Moon and planets were observed on 13 nights, and a number of observations were made of the errors of the Fry telescope mounting, in order to determine its constancy throughout the year. This arose from the method used for observing the reappearance of stars occulted by the Moon. This is as follows :—

The errors of the mounting are applied to the R.A. and declination of the star before the telescope is set to observe a reappearance. If this setting is correct to within one or two minutes of arc, it is found that the observations are greatly facilitated.

The Radcliffe 24-inch Photographic Refractor.—During the Spring the Wilson Observer superintended the dismantling of this instrument and its removal, together with the Observatory dome and rising floor, to London, the labour and cartage being provided by Messrs. Leslie & Co. of South Kensington. In all, there were 12 10-ton lorry loads of material, of which 3 went to the Observatory and the remainder to the University Headquarters at South Kensington, where the telescope is being stored pending obtaining the necessary money for its erection at Mill Hill. The Borough of Hendon has agreed to lease to the University an additional strip of ground on the west of the Observatory site for the erection of a building in which to house the newly acquired telescope. In addition to this, a number of important accessories were brought by road from the Radcliffe Observatory to Mill Hill, including a Grubb measuring machine, a set of astrographic charts of the Northern Hemisphere, and the proper motion and parallax plates taken with the Radcliffe refractor. The Director and staff of the Radcliffe Observatory gave the most valuable assistance in dismantling and packing the apparatus, all of which arrived without damage.

The I.A.U. Meeting in Paris.—The following exhibits were shown in Paris : experimental transitgraph, previously referred to ; plans and photographs of the 8-inch cœlostat telescope ; a double-slit interferometer, once exhibited at the R.A.S. ; a vibrograph, by Casella ; a floating zenith mirror, by Wood ; and an artificial double star suitable for students' observations.

The various exhibits were demonstrated by the Wilson Observer, who attended the meeting.

Occultations.—Following a suggestion of Professor Brown, the annual list of occultations was not published as usual in the *Monthly Notices* during the autumn, but has been delayed until this year, so that in the future the annual lists will be from January 1 to December 31. The serial numbers of the observed occultations during 1935 are from 90 to 125 inclusive.

University College Observatory.—The work, which is mainly instructional, has been carried on as in previous years. The 10-inch reflector by Calver has now been re-conditioned, and the mirrors have been coated with aluminium. The Synchronome sidereal clock in the transit house, which gave a good deal of trouble during the past year, has been put right by the makers, and is now going in a satisfactory manner.

Radcliffe Observatory, Oxford
(*Director, Dr. H. Knox-Shaw, Radcliffe Observer*)

The observatory in Oxford was vacated in June on the termination of the five years' lease obtained when the site was sold in 1930. Final approval of the scheme for removal of the observatory to Pretoria was given by the Court of Chancery in July.

The disposal of the contents of the observatory occupied the staff during the first half of the year. The 24-inch and 18-inch double refractor was presented to the University of London, together with the series of plates

obtained with the telescope and the Grubb measuring machine ; the 10-inch Barclay refractor to Marlborough College ; and the old instruments to the Museum of the History of Science, Oxford, and the Science Museum, South Kensington. About one-tenth part of the books in the library was selected as suitable for removal to the new Radcliffe Observatory ; those remaining were disposed of by gift to the Bodleian and other libraries in Oxford, and by sale. The original observation books of the first three observers, Hornsby, Robertson, and Rigaud, were presented to the Society, and what appears to be the MS. of Flamsteed's original catalogue for the *Historia Cœlestis* to the Royal Observatory, Greenwich.

Mr. W. H. Robinson retired on June 30 after serving the observatory most faithfully for nearly fifty-six years. Mr. H. G. S. Barrett is now assisting in the reduction of the Eros observations at Greenwich. Mr. J. G. Balk remains at Oxford to continue the meteorological work, which has been taken over by the University. Mr. E. G. Shirley is working at the Solar Physics Observatory, Cambridge.

An order for a 74-inch reflector, which will be the only telescope at the new observatory in Pretoria, was placed with Sir Howard Grubb, Parsons & Co., in August. It will be generally similar to that recently built by that firm for the David Dunlap Observatory, Toronto, but it will have in addition a *coudé* arrangement by which the optical beam can be sent down the polar axis to a fixed spectrograph. The pyrex disc for the large mirror will be cast by the Corning Glass Co., New York ; the five smaller mirrors will be of fused silica, and are being made by the Thermal Syndicate, Wallsend. The drive will be electric, an adaptation of that introduced by Messrs. McMath and Hulbert for their telescope at Michigan. It is hoped that the new observatory may be built and the telescope erected by the early part of 1938.

University Observatory, Oxford
(Director, Professor H. H. Plaskett)

Staff.—In addition to the permanent staff, which remained unchanged, the observatory again had the services of Dr. Zanstra during the summer. Graduate research in astrophysics was also undertaken during the whole or part of the year by Miss M. G. Adam, Dr. J. D. Babbitt and Mr. T. L. Page. The Synner Senior Student in Astronomy, Dr. R. V. Jones, continued his work at the Clarendon Laboratory on the design and construction of thermocouples and bolometers.

Equipment.—The solar telescope, erection of which was completed by Grubb, Parsons & Co. early in March, was subjected to a number of optical and mechanical tests during the spring and summer. The instrument gives excellent definition, and its mechanical performance, after the correction of a number of minor faults by the makers, is equally good. Owing to shortage of funds the 30-foot spectroscope still lacks the temperature control, the slit and plate-holder breech and the optical bench with guiding disc. As far as can be told in its present incomplete form, the instrument

gives the high resolving power and good definition which had been anticipated from the use of the large glass prisms. This new solar equipment was formally declared open on June 11 by the Vice-Chancellor at a ceremony attended by many astronomers and members of the University. After inspecting the instruments the company attended a lecture by Sir Arthur Eddington on "The Physics of the Sun."

Astrophysics.—With the solar telescope and the Hilger medium glass spectrograph a series of calibrated spectra of solar granulation was obtained during September and October. These spectra and some earlier ones secured at Victoria have furnished several thousand intensity determinations of the variation in surface-brightness due to the granulation. From these measures some interesting conclusions have been reached on the origin of this phenomenon. The observational determination of the surface-brightness of the centre of the solar disc as a function of wave-length was completed during the summer, and some preliminary work on the darkening towards the limb put under way.

Mr. Page's observational study of the continuous spectrum of some typical planetary nebulæ is now complete. He has shown that the visual continuous spectrum ($\lambda\lambda$ 3800–5000) is produced by particles giving non-selective scattering with an optical depth greater than unity; further, he finds that the Balmer continuous spectrum has an intensity distribution corresponding to an electron temperature of some 2000°. Accounts of this work, and that on solar granulation, will shortly be communicated to the Society.

Astrographic Catalogue.—The work on the Potsdam zones $+32°$ and $+33°$ goes forward satisfactorily under the direction of Mr. Bellamy. The observational work is 83 per cent., and the measurement and reduction 76 per cent. complete. As in 1934, considerable assistance in the measurement has been afforded through the generosity of Dr. Wilfred Hall.

Seismology.—Owing to the illness of Mr. Hughes, work on the Seismological Summary was seriously handicapped during the latter part of the year. However, the second quarter for 1931 is ready for the press, and the two previous quarters were printed and distributed during the year. Miss Bellamy has published a continuation of Professor Turner's "Catalogue of Earthquakes"; essentially it is an index to the Summary for the years 1925–30. A new metal globe with auxiliary apparatus for the preliminary determination of epicentres has been provided by a grant from the Gray-Milne Fund and a generous gift from Mrs. Turner.

Norman Lockyer Observatory, Salcombe Hill, Sidmouth
(*Director, William J. S. Lockyer, M.A., Ph.D., Major (late R.A.F.)*)

The Kensington 9-inch prismatic camera has been in regular use for photographing the spectra of selected Be-type stars, and of Nova Herculis 1934 in the early part of the year. The number of negatives secured during the year was 185, of which 46 were of Nova Herculis. The Zeiss triplet lens

attached to this instrument has been used occasionally during part of the time of the exposure of the spectra, 19 negatives being taken ; and occasional photographs have also been taken with the fixed meteor cameras which are erected near the Kensington dome. The McClean 12-inch prismatic camera was used in the early part of the year, mainly for photographing the spectrum of Nova Herculis. The number of negatives obtained was 39, of which 25 were of the Nova.

The number of fine nights was 113, which is below the average annual number. Successful observations were made on 92 nights, and 227 were completely overcast.

Work has been continued on B-type stars which show bright hydrogen lines in their spectra. The spectrum of γ Cassiopeiæ in particular has shown some very interesting and unusual changes, both in the emission and absorption lines. An account of some of these changes was given in *M.N.*, **95**, 520, and **96**, 2 ; and further changes have been observed since that date.

B-type stars in general still continue to receive attention from the points of view of classification, parallax, and variation. Two new short-period spectrum variables of the β Canis Majoris type have been discovered, but have not yet been observed for a sufficient time to deduce their periods.

The observatory is open to the public on Wednesday afternoons, and in addition was visited by large parties by special arrangement. The total number of visitors who attended during the year was 301.

The nineteenth annual general meeting of the Norman Lockyer Observatory Corporation was held in London on 1935 June 25.

Stonyhurst College Observatory
(*Director, Rev. J. P. Rowland, S.J.*)

The usual routine work of the observatory has been maintained without interruption throughout the year, and the results of the meteorological, magnetic and seismological observations have been forwarded to the official centres.

Observation of the solar surface was made on 270 days, on 260 of which drawings showing all spots were obtained, and these have been supplemented by copies of drawings made at Zurich on 89 days, kindly supplied by Professor Brunner, to whom, in return, we have been able to supply copies of our drawings for a number of dates on which observation was not possible at Zurich. There remain 17 days for which no statistics are available. Counts of groups and nuclei have been sent quarterly to Professor Brunner for the preparation of "Sunspot Numbers" and "Solar Character Figures," and "Daily Magnetic Character" figures have been supplied to the International Meteorological Organisation at De Bilt.

Solar activity shows a marked increase on last year, the number of spotless days falling from 175 to 24, and the mean daily area of spots, in units 1/5000 of the disc, increasing from 0·58 to 3·12. Solar activity was

especially great in November and December, in which months the mean spotted area was 8·19 and 8·84 respectively.

Magnetic activity, for the first time in the present solar cycle, shows an increase, the mean daily ranges in declination and horizontal force being 14′·2 and 59·3 γ as against 12′·4 and 53·1 γ in 1934. The number of days of "moderate" disturbance, on the Stonyhurst system of classification, increased from 77 to 94, and of "greater" disturbance from 10 to 15. There were again, as last year, no disturbances ranking as "very great," or true magnetic storms. The great solar activity of November and December was not accompanied by any corresponding increase in magnetic activity.

During the year 119 earthquakes were recorded, the most notable being that which destroyed Quetta on May 30.

The Director attended the meeting of the International Astronomical Union at Paris in July, as a member of Commission 10. During the meeting he was elected to serve also on Commission 11.

Towards the end of the year an improvement was made in the driving clock of the 15-inch equatorial by the provision of an automatic motor-driven continuous winding gear, which eliminates change of rate during winding, and by the incorporation of a differential gear between the clock and the right ascension tangent screw, with pendulum clock correction for irregularities in the running of the driving clock, and provision of motor-driven slow motion in right ascension. The electric circuits of this new control are not yet completed, but it is hoped to have them working at an early date, when it is expected that the instrument will be much more satisfactory for any photographic work which may be undertaken.

Dominion Observatory, Ottawa, Canada
(*Director, Mr. R. Meldrum Stewart*)

Meridian Work and Time-Service.—After reversal of eye and object ends of the meridian circle, observations were recommenced in May and were obtained on 172 days. Observations for clock corrections were made also on 84 nights with the broken-type Cooke transit. The primary sidereal clocks have kept their rates about as well as anticipated, excepting that the synchronome was put out of use for some days by the earthquake of November 1. The synchronized time-service has been applied to the Pulsynetic master clock in the Confederation Building. As previously, time has been distributed by clock-beats over the telephone, by telegraph line, by broadcast through radio station CRCO and by short wave from the observatory. The lines from the synchronome relays in the observatory to the two radio monitoring laboratories have been found very useful to them and have made available, for observatory use, the crystal clocks in the radio stations. Time-signals were received regularly by wireless from Nauen, Rugby, Bordeaux, Annapolis, Monte Grande and Rio de Janeiro, and the results sent to the Bureau International de l'Heure. To the chronographic equipment there has been added a photochronograph kindly

lent by the Department of Marine. The usual amount of repairs, overhauling and rating of watches, chronometers, and other small instruments, has been done for other branches of the Government service.

Solar Physics.—Days of the best quality for solar observations were abnormally scarce. It was impossible to secure the usual series of spectrograms when the Earth was near the solar equator, in early June. Some 160 spectrograms recording mainly spectra of the equatorial and polar limbs, centre, and midway, with iodine absorption spectra at λ 5600, and 44 photographs of the solar disc, were obtained. Final results derived from the measurements and re-measurements of the solar equatorial velocity of rotation, from the 1910 spectrograms, after practically eliminating the errors due to the micrometer-oil, were : 32 observations, 12 lines, λ 4376–λ 4574, 1·959 km. per second ; 32 observations, 10 lines, λ 5528–λ 5593, 1·933 km. per second ; and 68 observations, 6 lines, λ 5586–λ 5590, 1·920 km. per second. In the first group no appreciable difference in velocity was found between two groups of six lines each differing by 1400 km. in average elevation in the solar atmosphere. In the observations in the yellow region differences were found between different lines, ascribable to the blending of general sunlight from cirrus haze.

The 15-inch Equatorial.—The observational work during the first part of the year was restricted entirely to the spectrograph. During the latter part the photo-electric photometer was in use, when work of a more experimental nature was carried on. With the spectrograph a series of plates was taken of Nova Herculis 1934, and this was continued until it was considered inadvisable to do further work of this nature with the equipment. Some experimental work was done with the Moll microphotometer and a few minor changes made. These resulted in sharper tracings being obtained. Graphs were made from the series of plates of Nova Herculis. The computation of preliminary orbital elements was completed for the star λ Andromedæ for the years 1924, 1925 and 1926. As in former years, the telescope was in use for public demonstration every clear Saturday night.

Photographic Photometry.—The International Cepheid Programme was continued, one hundred and eight plates being obtained during 1935. Observations were completed on the fields of X Scuti, UZ Scuti, RU Scuti, TY Scuti, Z Scuti, AV Cygni, CD Cygni, S Vulpeculæ and SV Vulpeculæ, and plates of Z Lacertæ and RR Lacertæ were obtained for light-curves. Nova Herculis was observed throughout the year and measurements of the plates have been begun. Series of exposures on Polaris were measured to determine the necessary corrections due to the curvature of the camera field ; further measures are required to complete a satisfactory table of corrections.

Seismology.—During the year, 328 earthquakes were recorded at the Ottawa station, and of this number 12 were reported to the Press and to Science Service, Washington, D.C. The investigation of the Timiskaming earthquake of November 1 has been sufficiently advanced for the preparation of a preliminary report as to its epicentre and the depth of focus. The co-operative programme for the study of seismic conditions in Quebec

Province was maintained by continuous operation of short-period seismographs at Shawinigan Falls and Seven Falls. The auxiliary teleseismic stations at Saskatoon, Seven Falls and Halifax were kept in continuous operation. Seismic registrations were reported regularly through the medium of a monthly bulletin distributed to the principal seismic stations of the world. The *Bibliography of Seismology* appeared regularly during the year. The number of collaborators has increased, and it is believed that the reports are more complete on this account. Considerable work was done on a research problem directed toward a checking of the results heretofore obtained for the structure of the Earth. This was done with a view to determining the extent to which the published results are affected by the personal tendencies peculiar to the various investigators. The work is still in progress. The annual meeting of the Eastern Section of the Seismological Society of America was held in Ottawa 1935 May 27–28. The Seismologist presented a paper on the subject "The Precision of the Seismological Evidence as to the Structure of the Deep Interior of the Earth." Mr. Doxsee described the special recorders used at Ottawa and explained their adaptation for use with the Milne-Shaw seismographs. The earthquake of 1935 November 1 had its origin near Timiskaming, Quebec. A complete study of this earthquake has been undertaken, a month being spent in field-work. The location data now tentatively adopted are the epicentral co-ordinates : $\phi = 46^\circ\ 47'$ N., $\lambda = 79^\circ\ 04'$ W., the focal depth = 200 km., and the focal time = $6^h\ 03^m\ 40^s$, U.T., 1935 November 1.

Terrestrial Magnetism.—During the year observations of the three magnetic elements, declination, inclination and horizontal intensity, were made at thirty-three stations. Twenty-seven of these are repeat stations which will furnish secular change data, and six are new. Five of the latter are in the vicinity of former stations. This duplication is the result of the practice followed of establishing a new station where a former station appeared likely to be unsuitable for future occupation. The work was confined to two separate sections of the country. Eighteen stations are between latitudes 51° 09′ and 56° 24′ N., and longitudes 94° 36′ and 120° 53′ W., and the remaining fifteen are between latitudes 45° 23′ and 51° 26′ N., and longitudes 57° 09′ and 76° 36′ W. In addition to the field-work the usual instrumental comparisons were made at Ottawa in the spring and fall.

Gravity.—Owing to restricted appropriations no pendulum field-work has been carried on since the season of 1930. The general report on all gravity work in Canada is now in press.

Applied Geophysics.—In co-operation with the Geological Survey of Canada, three traverses, covering a total distance of thirty-nine miles, were made with a torsion balance and magnetometers across the buried Pre-Carboniferous ridge associated with the occurrence of natural gas and oil in the vicinity of Moncton, New Brunswick. Particularly interesting results were obtained along the main traverse, where it is apparent that the deduced relative values of gravity are closely related to the magnetic anomalies and also to the depth of buried structure, which varies between limits of a few hundred feet and several thousand feet.

Publications.—Publications during the year included six numbers of the regular series of Publications of the Dominion Observatory, namely, Vol. vi, *Spectroscopic Investigations of the Sun*, Part I, *General Outlines of Observations, Instruments and Methods*, Secs. 8 and 9 ; and Vol. xii, *Bibliography of Seismology*, Nos. 3, 4, 5, 6 and 7. Other papers published elsewhere or issued in mimeographed form included the following : *Sunspots and the Forest ; Tables of Measurements of Annual Growth-rings of* 66 *Trees ; Seismological Bulletin* (monthly)*; Wireless Time Signals* (monthly)*; Saturday Evening Program* (quarterly).

David Dunlap Observatory, University of Toronto
(Director, Professor R. K. Young)

Opening.—The observatory was opened on May 31, and work was begun with the 74-inch telescope and the Hilger one-prism spectrograph attached on 1935 June 9. The 19-inch reflector has not been completely mounted. The following comprise the present observing staff of the observatory : The Director, Dr. F. S. Hogg, Dr. P. M. Millman, Dr. J. F. Heard. Dr. Helen S. Hogg has acted as part-time voluntary research associate.

Spectrographic Work.—The one-prism spectrograph has been used to measure the radial velocity of the fainter stars in and near the Kapteyn areas. There have been secured 396 spectra of 346 stars, ranging in photographic magnitude down to 8·0. Investigations of the spectrograph show that it gives remarkably good definition and focus and is free from flexure. The 74-inch mirror of pyrex is a great improvement over mirrors made of higher expansion glasses. It keeps a good figure under trying temperature variations.

Newtonian Focus.—Dr. Helen Sawyer Hogg has continued her programme of work on variables in globular clusters begun at the Dominion Astrophysical Observatory three years ago. Sixty-six direct photographs have been secured. Periods are now being determined for the fifty new variables in N.G.C. 6934 and for seventy-five new ones in N.G.C. 6402. Twenty-eight periods have been determined in these two clusters. The clusters N.G.C. 6254, 6760, 6779 and M 13 are also under observation for the discovery of new variables and the determination of the periods of those found earlier.

Meteor Research.—Dr. P. M. Millman has continued a programme of visual and photographic observation begun in 1933 before the completion of the telescope. To date a total of 12,700 observations have been made at the observatory and co-operating stations. Photographic programmes have resulted in six meteor spectra during a total exposure time of 143 hours and 8 meteor trails in an exposure time of 46 hours with direct cameras.

Dominion Astrophysical Observatory, Victoria, B.C.
(Acting-Director, Mr. W. E. Harper)

Two new appointments to the staff were made during 1935. Dr. R. M. Petrie, formerly with the Detroit Observatory at Ann Arbor, and Dr. Andrew

McKellar of the Massachusetts Institute of Technology were appointed astronomers and reported for duty at the end of April and May respectively. Both had previous experience at this observatory. A graduate student, Jacques Fox of the University of Saskatchewan, spent a couple of months at the observatory during the summer vacation as a volunteer assistant.

The observing weather was about 10 per cent. above the average, as on 214 nights with 1390·5 hours observing 1470 plates were secured. The seventeen-year average shows 202 nights with 1245·9 hours observing and 1352 plates. The Cassegrain mirror was away at Pasadena being aluminized during January, but as it happened the weather was extremely poor and consequently but little observing was missed. Our thanks are due to the Mount Wilson Observatory for aluminizing this secondary mirror, which has made possible the securing of denser spectra in the violet region in a shorter time.

In connection with our spectroscopic work in general, considerable attention has been given to the question of the most suitable plates for the various problems, and quantitative tests upon the speed and grain of several Ilford and Eastman emulsions have been made, using the recently installed registering microphotometer for this purpose. Two joint papers on this subject have been presented to the meetings of the American Astronomical Society, and the results found were of considerable interest to others engaged in the work.

In the matter of tables for reducing the plates and obtaining the radial velocities, it has been felt that there has not been as much uniformity in the matter of wave-lengths as should prevail in one institution. Hence a set of reduction tables, twenty-four in all, has been prepared covering the various dispersions and spectral classes. The use of these common tables by all observers here should tend to consistent results within the institution. For several years it has been known that the curvature correction for our instrument should be $-0{\cdot}7$ km./sec. instead of $-1{\cdot}0$ km./sec. and it is proposed, beginning 1936 January 1, to use the correct value in all our reductions.

The Acting-Director has prepared for publication the revisions of the periods and, as required, the orbital elements for 64 spectroscopic binaries. In one case the period was radically wrong ; in a few other cases the error was considered sufficient to justify a new solution, but in general only minor changes were found. The additional observations were made simply to effect refinements in the period and were not numerous enough to discuss possible secular changes in the orbital elements. The paper containing the results is almost through the press.

The programme of Class A stars, which has been under way for several years, was not pushed during the year, owing to press of other work. The results for 912 stars were arranged for publication and the manuscript typed, but, in the case of some stars suspected of a binary nature, additional plates were secured and these have not yet been measured.

The orbits of three spectroscopic binaries have been determined also by Mr. Harper. The stars are Boss 3109, Boss 5536 and the eclipsing variable AR Aurigæ. In the case of the latter star the true period was found to be

double that previously accepted from the photometric work. A study of the two spectra recorded suggests that the stars are somewhat similar, of type Ao, the fainter one being about 75 per cent. as luminous as the brighter. The eighth magnitude star Boss 5536 also shows two spectra, and the orbital velocity residuals are of such a character as to suggest an eclipsing system. The star Boss 3109 shows a single spectrum only and has a period of 32·864 days. A revision of the orbit of H.D. 185936 was also made on the basis of the slightly different value of the period found from photometric work on this eclipsing system. The results are not wholly satisfactory and further observations will be made.

Dr. J. A. Pearce has continued his investigations of the orbital elements and masses of eclipsing variables and spectroscopic binaries. The three well-known variables, U Ophiuchi, U Herculis and U Coronæ Borealis, have been thoroughly re-observed, fine-grained plates being employed. In U Coronæ Borealis, stellar and interstellar calcium lines were found to co-exist, the lines being blended throughout the greater portion of the 3·45 days period. The inclusion of the blended calcium velocities by Plaskett in his 1920 orbit vitiated his results. A revised orbit based upon a re-measurement of the 1920 plates, excluding the calcium lines, is in complete agreement with the 1935 orbit. No secular changes were observed.

A rotation of the line-of-apsides was detected in the double-lined B3*k*–B5 binary, H.D. 199081. The 1935 orbital elements, when compared with the redetermined 1910 elements, indicate an advance in ω of $17^{\circ}\cdot5$ in 25 years, the period of rotation being 525 years. Separate least-squares solutions for the orbital elements of each component of the system confirm the results. The other orbital elements have remained unchanged.

The observations of the O-type system Y Cygni have been closed, 61 spectra well-distributed in phase having been secured in the period 1933–35. The two long-period Class B stars of high eccentricity, α and π Andromedæ, have been re-observed for the determination of changes in their orbital elements. Two series of observations of RZ Cassiopeiæ through principal minimum have been secured, and further observations will be taken to detect the rotation effect.

The photoelectric microphotometer formerly in use as a direct reading instrument has been redesigned by Dr. C. S. Beals and rebuilt. The instrument has been fitted with a new optical system employing two analysing slits and a new electrical system consisting of a single tube valve amplifier operated on a potential of 10 volts. A camera for self-recording has been installed, features of which include continuous supply of paper up to 100 feet, means for impressing co-ordinate scale on sensitive paper, magnification of × 20 and × 100 with clutch and gear-shift lever for rapid change, and mean error of linear measurement of 0·002 mm. Extra galvanometers and photo cells make it possible to impress records of the two iron comparisons on the sensitive paper simultaneously with that of the star spectrum.

Observations of interstellar intensities have been continued with results which may be summarized as follows: The predicted relation between intensity and radial velocity appears not to be present in any marked degree

for the stars so far examined. Evidence pointing to peculiar motion in the interstellar cloud has been obtained from analysis of radial velocities of the Perseus and Cygnus clusters. The intensity ratio K/H for some of the nearer stars appears to approach the value 2 : 1, suggesting a density lower than current estimates for interstellar matter. Equivalent widths in km. per sec. of *Na* lines are greater than those of Ca^+ and this disparity is more marked for nearer stars. Some interstellar lines have been found to exhibit complex or irregular profiles. The tentative conclusion is reached that peculiar or irregular motion of parts of the interstellar cloud is the principal factor in forming the line profile for stars of distances up to 1000 parsecs.

Dr. R. M. Petrie has completed the orbit of the double-line spectroscopic binary Boss 4745, a rather difficult star since the component spectra are resolved for only about 10 per cent. of the period of 9·81 days. Several bright spectroscopic binaries, for which orbits are already published, are being observed, in most cases with high dispersion in order that accurate orbital elements may be secured. The aim of the investigation is to provide data relevant to the question of orbital changes by a comparison with the early observations, and to revise the orbital elements where desirable. Several stars of variable radial velocity are also being observed to secure the spectrographic orbits.

A number of spectroscopic binaries in which two spectra are visible are being observed at certain phases with high dispersion, for the purpose of securing spectral line profiles. The object of this investigation is to secure the relative brightness of the components of such systems. A method for the measurement of this quantity has been devised, and preliminary results on eclipsing binaries, as test objects, indicate that the method is feasible. It is planned to extend the study to a greater number of systems with single-prism dispersion.

Dr. Andrew McKellar has carried out measurements on high dispersion spectrograms (taken with the 35-foot concave grating at the Massachusetts Institute of Technology), of the red Σ, Σ band system of the Li_2 molecule. From the measurements on both the main (Li^7 Li^7) and isotopic (Li^6 Li^7) bands, computations were made to evaluate the mass ratio of the lithium isotopes. This was done in an effort to explain the discrepancy between the mass ratio as determined from band spectrum data and by other methods. The orbit of the spectroscopic binary star Boss 4217 was calculated from radial velocity measurements on thirty-one spectrograms obtained this year. A quantitative study of intensities of the main and isotopic bands due to the C_2 molecule occurring in R and N type stars was commenced, a considerable number of spectrograms for use in this problem being secured.

A few improvements in the instrumental equipment may be noted. Besides the aluminizing of both Newtonian and Cassegrain mirrors through the courtesy of the Mount Wilson Observatory, and the redesigning of the photometer as previously referred to, changes have been made in the dome mechanism permitting complete centralized control on the main observing floor. Recent investigation also has shown that the objections previously

levelled at the rotating sector for plate calibration are no longer valid, provided the speed of rotation of the sector is sufficiently rapid. A motor driving the sector with a speed of 100 revolutions per second is now used and the rotating sector now supersedes the wedge formerly employed in calibrating our spectrum plates. Experiments are being made to test the possible existence of systematic differences between calibrations impressed on plates by these methods as well as by the use of a step slit.

During the year No. 4 of Vol. 5 and Nos. 12, 13, 14, 15 and 16 of Vol. 6 of the *Publications D.A.O.* have been sent to press. In addition 24 papers by members of the staff have been prepared for presentation to various scientific meetings.

Of minor note it may be mentioned that the Public Works Department has repainted all the buildings, office, dwellings and dome, the latter having its exterior coated with aluminium paint which makes it quite striking. A much-needed sidewalk connecting office and dome was also constructed. Approximately 21,000 persons visited the observatory during the year, two hours on Saturday evenings being, as usual, devoted to visitors.

Helwan Observatory, Ministry of Public Works, Egypt
(*Director, Dr. M. R. Madwar*)

Time Service.—The time service was maintained as usual, the error of the standard Shortt clock No. 1 being determined from star transits. Rhythmic W/T signals were received daily from Bordeaux and Rugby during the morning.

The standard clock ran satisfactorily, the range in the daily rate throughout the year being $0^{s}.25$, and the range in the temperature of the clock room $17^{\circ}.5$ C.

The reversible transit circle was used regularly and 52 transits were taken throughout the year.

Reynolds Reflector.—The reflector was used on 101 nights and 200 plates were exposed as follows : 127 plates on nebulæ, 10 focus, 18 for the determination of the magnitude extinction coefficient at Helwan and 45 test plates.

General.—The usual meteorological, magnetic, seismological and solar radiation observations were continued. A Dye vertical force magnetometer was installed and, after certain initial difficulties were overcome, was working well at the end of the year.

Publications.—Helwan Observatory Bulletin No. 38, on the sixth list of nebulæ photographed, was published and duly distributed.

Nizamiah Observatory, Hyderabad
(*Director, Mr. T. P. Bhaskaran, M.A.*)

Work on the Hyderabad section of the *Astrographic Catalogue* was continued steadily throughout the year. The number of photographs

taken with the instrument was 121, of which 11 were to complete the series required for the catalogue zones $+36°$ and $+37°$; nine plates were exposed on the field of Nova Herculis 1934 in April and May, when the Nova was faint, and nearly all the remaining plates with centres in Dec. $-17°$ and $-18°$ were taken for the determination of proper motions by comparison with the plates of the former series under the blink comparator. The measurement of the plates was pushed forward as much as possible, the number measured in both positions for the catalogue being 60. The work of measurement and reduction of the Eros photographs taken during the opposition of 1931 is well in hand, and the final places of the minor planet have been derived from the measures for seven plates for comparison with the ephemeris.

Good progress has been made with the printing of vol. x of the *Hyderabad Astrographic Catalogue* containing the measures of photographs in zone $+38°$; the typescript of the whole volume, with the exception of the introduction, has been received from the printers, and it is hoped that this volume, as well as vol. viii, part 1, will be ready for publication early in 1936.

The Grubb equatorial was dismounted in 1935 June, just before the monsoon, for some extensive repairs to the dome of the telescope house which was leaking badly. The instrument was thoroughly cleaned and put back in December. As a consequence, systematic work with the telescope was restricted to the first six months of the year, in which 669 estimates of brightness of variable stars were obtained.

Sixteen occultations of stars by the Moon—all disappearances except one—were observed. Of these eleven were of stars fainter than the ninth magnitude observed during the lunar eclipse of January 19.

Observations with the Transit instrument were taken occasionally, as usual, for the determination of clock corrections.

The seismographs (two Milne-Shaw horizontal pendulums) have been in continuous operation and have registered 142 shocks during the year. Satisfactory records have been secured of the great Quetta earthquake as well as of the several after-shocks from the same epicentral region.

The usual meteorological observations, including those of upper winds by means of pilot balloon flights, were continued as in previous years.

Kodaikanal Observatory
Director, T. Royds, D.Sc.

There has been a further increase in all forms of solar activity when compared with the previous year.

Photoheliograms were obtained on 324 days, calcium flocculi plates on 309 days, calcium prominence plates on 289 days and $H\alpha$ flocculi plates on 261 days. One calcium flocculus plate for each day was sent to the Solar Physics Observatory, Cambridge, as in former years.

Under the auspices of the International Astronomical Union, K pro-

minence and $H\alpha$ disc spectroheliograms were collected from other observatories whenever complete observations were not possible at Kodaikanal. The statistical data regarding prominences seen at the limb and by absorption on the disc are published in half-yearly bulletins.

Daily character figures of solar activity according to $H\alpha$ bright flocculi and $H\alpha$ dark markings have been communicated to the Observatoire Fédéral, Zurich, for publication as in previous years. Daily character figures as derived from calcium flocculi from Kodaikanal photographs are furnished by the Solar Physics Observatory, Cambridge.

Regular observations were made with the Hale spectrohelioscope on all days excepting Sundays and holidays, whenever the weather permitted.

The Director and the Assistant Director continued their photometric studies of the calcium lines in different parts of the Sun's disc, and the Director continued his similar study of the hydrogen lines. The measures have been interpreted to give the densities of the atoms of calcium and hydrogen in the lower part of the Sun's reversing layer. Preliminary results give the following values :—

Neutral calcium	...	...	$7{\cdot}8 \times 10^{10}$ atoms per c.c.
Ionised calcium	...	...	$2{\cdot}1 \times 10^{13}$,, ,, ,,
Hydrogen (2-quantum state)		...	$3{\cdot}4 \times 10^{10}$,, ,, ,,

The Director has observed in full daylight the bright reversal of the infra-red oxygen triplet in the Sun's chromosphere, which is evidence of great abundance of oxygen to considerable heights in the chromosphere.

Union Observatory, Johannesburg
(*Union Astronomer, Mr. H. E. Wood, M.Sc.*)

26½-Inch Grubb Visual Refractor.—The number of visual micrometrical measures of double stars made during the year was 1906. With the eyepiece interferometer, 23 measures of suitable double stars were obtained ; 60 photographic plates of double stars were taken.

Franklin-Adams Star Camera.—During the year 1555 plates were taken with this instrument. The distribution of the plates was as follows :—

Minor planet regions and star maps	...	...	468 plates.
Variable star regions	...	...	...	...	975 ,,
Comet regions	...	...	...	...	...	112 ,,

Two new comets were discovered during the year with this instrument.

Comet 1935*a* was found by Mr. E. L. Johnson when photographing map regions in 52° South Declination. The comet was observed here from January 7 to February 24, when it passed out of reach into high northerly declinations.

Comet 1935*b* was found by Mr. C. Jackson when photographing minor planet zones and was observed from June 3 to July 19. This comet has an unusually large perihelion distance and was at first thought to be a minor planet.

Comet Forbes 1929 II was unsuccessfully searched for on many occasions between May and September.

Comet 1935*d* (van Biesbroeck) was observed from July 3 to October 29. This comet was discovered by van Biesbroeck on August 21 and, after an ephemeris had been computed, a number of images were found on earlier Franklin-Adams plates.

109 new minor planets were discovered during the year, and elliptic orbits have been computed for 8 new minor planets. 748 approximate positions and 142 accurately measured positions of minor planets were forwarded to the Astronomisches Rechen-Institut.

Occultations of Stars by the Moon.—The programme of the last few years has been maintained without alteration. 148 occultations were observed during the year. The results of the year's observations are as follows :—

		B	″
	1935·11	5·2	2·8
	·37	7·5	4·1
	·63	6·9	3·8
	·80	5·1	2·8
Mean for year	·55	6·6	3·6

These results are, as in former reports, from disappearances at the dark limb only. The second column indicates the time by which the moon has arrived too early at any longitude and the third column the amount by which the Moon is ahead of its tabular longitude.

Union Observatory Circulars.—Circulars Nos. 93 and 94 were distributed during the year. Nineteen Southern Star Maps were issued with these circulars. Of the 556 maps required to cover the sky south of $-19°$, 526 maps have already been issued, leaving only 30 maps to complete the series.

Miscellaneous.—Dr. H. van Gent of the Leiden Observatory has continued his photographic observations of variable stars throughout the year and has also taken some plates of double stars with the 26½-inch refractor.

Dr. van den Bos was on leave from May 18 to December 21. He attended the I.A.U. meeting at Paris in July and visited the observatories at Leiden, Paris, Meudon, Potsdam, Neubabelsberg, Bergedorf, Harvard, Yerkes, Mount Wilson, Lick, Tokio and Lembang.

The number of visitors to the observatory during the year was 1681.

Adelaide Observatory

(*Director, Mr. G. F. Dodwell, B.A., Government Astronomer*)

The work of the Adelaide Observatory has been continued on the same lines as described in last year's report.

In regard to the International Latitude Observations 1462 pairs of latitude stars were observed on 141 nights, principally by Messrs. A. L. Dawson, B.Sc., and A. E. Markey.

This is the largest number of observations obtained in one year since the work was started here.

The retirement of Dr. H. Kimura from the Presidency of the International Latitude Committee and from the direction of the Central Bureau for this work, owing to health reasons, is greatly regretted here, especially as he had been able to establish personal contact with the southern hemisphere latitude observers at Adelaide and La Plata, and his constant helpful advice and interest were greatly appreciated.

Magnetic observations have been continued, and an arrangement has been made with the Director of the Watheroo Observatory to send our field instruments to Watheroo at an early date for comparison with international standards.

A study of ancient and mediæval observations of the obliquity of the Ecliptic in the light of Wendelin's "lost manuscript," published in 1933 by the Astronomical Laboratory of the University of Louvain, has been made, and a paper on these results is in course of preparation.

Commonwealth Solar Observatory, Canberra, Australia
(Officer-in-Charge, Mr. W. B. Rimmer)

Solar Radiation.—An Elster & Geitel photo-electric photometer has been obtained, and is being used to measure the relative intensity of the solar radiation in the ultra-violet region below 3200 A.

Sky Radiation.—A study has been made of the brightness of the daylight sky, giving particular attention to the region in close proximity to the Sun. Calculations of the theoretical brightness for a pure dustless atmosphere have been made; the difference between theory and observation throws some light on the problem of absorption and scattering of solar radiation by dust in the Earth's atmosphere. An account of the work is in course of publication.

Sun Telescope.—A spectroscopic method of determining the total water-vapour content of the Earth's atmosphere has been developed. In this method the intensities of water-vapour lines in the yellow region of the solar spectrum are compared with those of adjacent solar lines. To obtain absolute values the results are calibrated by the values given by Hann's equation, the water-vapour pressure at the Earth's surface being determined by a ventilated psychrometer. An infra-red spectrograph by Kipp & Zonen is being brought into use, and the determination of the total water-vapour in the path of the Sun's rays, by measurement of the absorption bands in the infra-red as developed by Fowle, is being undertaken.

Atmospheric Electricity.—Continuous records of the potential gradient as well as daily measurements of the conductivity, number and mobility of the small ions have been continued. The results of mobility measurements made in 1934 are in course of publication. Automatic recording of the mean life, rate of production and concentration of small ions has been continued, and a series of measurements of Earth radiation has been obtained.

Cosmic Radiation.—Continuous records of the intensity of cosmic

radiation have been made since 1935 July 1. Efforts are being made to carry out a carefully standardised set of observations over a considerable period. The ionisation vessel is mounted in a thermostatically controlled room. Attention is being given to the measurement of the diurnal variation of the intensity of the radiation and the evaluation of the barometer effect; the azimuthal asymmetry of the filtered radiation is being investigated, also the occurrence of "bursts."

Radio Research.—Observations with the Cathode Ray Direction Finder and Continuous Recorder have been continued in close co-operation with an officer of the Commonwealth Meteorological Bureau in order to assess, in particular, the value of "atmospherics" data for weather-forecasting purposes. From the results of the C.R.D.F. observations carried out simultaneously at Canberra and Melbourne, a map is being prepared showing iso-intensity contours for thunderstorms around Canberra. From this, knowing their intensity and direction at one station only, actual locations of thunderstorms can be made.

Apparatus has been installed for measuring the heights of the ionospheric reflecting layers, and the continuous recording of these heights has recently been commenced.

Publications.—Publications during the year include *Memoir* No. 5 of the Commonwealth Solar Observatory, in two parts: Part 1, "The Intensity of Fraunhofer Lines in the Region 4036–6600 A."; Part 2, "Fraunhofer Intensity Tables." A paper, "Continuous Observations of the Rate of Production of Small Ions in the Atmosphere," appeared in *Gerlands Beitrage zur Geophysik* (**43**, pt. 4, pp. 359–378, 1935). Also a paper, "Simultaneous Observations of Atmospherics with Cathode Ray Direction Finders at Toowoomba and Canberra," appeared as *Bulletin* No. 89 of the C.S.I.R. (Report No. 8 of the Radio Research Roard); this work was carried out jointly with the Radio Research Board. Other papers are in process of publication.

General.—The programme of work, as outlined in the reports of previous years, has been continued.

Melbourne Observatory

(*J. M. Baldwin, M.A., D.Sc., F.Inst.P., Government Astronomer*)

The astronomical observational programme for the year has been confined to the list of Fundamental Stars with the 8-inch transit-circle and to southern long-period variable stars with the 8-inch equatorial. The results of the latter have been published regularly in *Popular Astronomy* with those of other members of the American A.V.S.O.

A machine for the computation of refractions, modelled on that described by P. Calot in the *Journal des Observateurs*, **12**, 21, 1929, was constructed during the year and has proved very convenient.

The only progress that has been possible in the *Astrographic Catalogue* has been in the computation of the definitive plate constants, but no funds

have been available for any progress in the printing of the *Fourth* and *Fifth Melbourne General Catalogues* or vols. iv and v of the *Astrographic Catalogue*.

Seismological and magnetic work has been carried on as usual. Seismological bulletins have been issued quarterly, and a volume containing hourly values of the magnetic elements at Toolangi for the four years 1928 to 1931 has been published and distributed.

Riverview College Observatory, Sydney, N.S.W.
(*Director, Rev. W. O'Leary, S.J.*)

In connection with research on variable stars 1166 plates were taken with the Zeiss Astrotriplet up to the end of November. A blink comparator, designed by Rev. P. Baker, S.J., and the Director, was constructed in the observatory workshop. A second one, of the same design, was constructed for the observatory by Mr. K. Beames of Sydney and has been in operation for some months. A number of new variable stars have been discovered with these instruments.

Observations of occultations of stars by the Moon were commenced in August. Nine occultations have been observed, the weather having been particularly bad since the beginning of October.

Riverview Publication, No. 1, containing results of photographic observations of variable stars, is ready for distribution.

Seismology.—Up to the end of November 171 earthquakes were recorded, well below the average number.

The Dominion Observatory, Wellington, New Zealand
(*For the Year* 1934)
(*Director, Dr. C. E. Adams, Dominion Astronomer and Seismologist*)

The time-service has been maintained and the regular daily signals transmitted. The total number of signals sent by the observatory was 3059. The signals are transmitted through the Government station ZLW, and through the broadcasting station 2YA at Wellington. The broadcasting station at Christchurch, 3YA, rebroadcasts the signals from 2YA. Radio time-signals from Nauen, Norddeich, Malabar, Bordeaux, Monte Grande, Washington, Honolulu and San Francisco have been recorded by using a chronograph with hand key. For signals sufficiently strong, the Marconi Magnetic Drum Recorder has been used. During the year 730 signals were received.

The reductions of the observations taken in 1933 October and November, during the International Longitude Programme, are still a long way in arrears owing to the small staff at the observatory. It is desirable that additional staff be obtained so that this important work can be completed as soon as possible.

Observations of sunspots with the 5-inch telescope belonging to the Wellington Philosophical Society have been continued. The reports have

been forwarded to Professor Brunner at Zurich. Observations were made on 103 days. There were 37 days when no spots were visible, and records and measurements were made of 102 centres of activity. Nearly all the spots had a high heliographic latitude, showing that the new solar cycle was well established.

By co-operation with the New Plymouth Astronomical Society, occultations of stars by the Moon have been observed, and the results forwarded to Dr. Comrie, H.M. Nautical Almanac Office, London. Four occultations were observed.

The Wellington City Council has again kindly given permission for the observatory staff to use the 9-inch Cooke photo-visual refractor. Considerable help in astronomy has also been given by the New Zealand Astronomical Society (Inc.) in the form of observations by reliable amateurs.

During the year 691 earthquakes were recorded on the seismographs at the observatory. The total number of earthquakes felt in New Zealand was 230, of which 170 were felt in the North Island, and 72 in the South Island. The most important earthquake during the year occurred on March 5 in the south-eastern part of the North Island, reaching a maximum intensity 9 on the Rossi-Forel scale. Epicentres were determined of 32 of the most important earthquakes in New Zealand, and also of 26 additional ones occurring in the South-West Pacific.

Besides the seismograph station at the observatory, subsidiary stations were operating throughout the year at Arapuni, Tuai, Hastings, New Plymouth, Bunnythorpe, Takaka, Greymouth, Christchurch, Chatham Islands. The station at Suva, Fiji, was closed at the end of July, whilst in October new stations were established at East Cape and Stratford.

During the year, Mr. L. Bastings, M.Sc., F.Inst.P., working as an Honorary Research Associate in Seismology, completed his detailed analyses of the records of the Buller Earthquake, and filed a copy of this work at the observatory. Mr. Bastings hopes to publish his results in sections from time to time.

The observatory has continued to publish a preliminary earthquake report each month, giving sufficient data for the determination of the epicentres of the principal earthquakes. These reports also include errors of the time-signals sent from the Dominion Observatory. With this report is also published a preliminary seismological report from the Magnetic Observatory, Christchurch.

Besides the preliminary reports, the following complete seismological reports were published during the year 1934 :—

E 32—Seismological Reports for 1932 January, February, March.
E 33—Seismological Reports for 1932 April, May, June.
E 34—Seismological Reports for 1932 July, August, September.
E 35—Seismological Reports for 1932 October, November, December.

Also the following bulletins :—

Bulletin No. 91—Report of the Dominion Astronomer and Seismologist for 1932.

Bulletin No. 92—Earthquakes : The Futility of Predicting them (R. W. de Montalk) (Reprint from *Bulletin of the Seismological Society of America*, vol. xxiv, No. 2, 1934 April).

An article on the Dominion time-service arrangements, giving full particulars of all the time-signals supplied by the observatory, was published in the *New Zealand Nautical Almanac*.

Articles on seismology and on mean time and time-service were published in the *New Zealand Official Year-Book*.

Mr. Robert Barker's Observatory, Cheshunt, Herts

Although 1935 was a bad year, a fair amount of definite work was accomplished.

A full programme on Mars was carried out, and a complete planisphere was obtained.

Several new lunar clefts and small formations were discovered, and further investigations were undertaken on the variability of 4 of Saturn's inner satellites and Iapetus, and on the markings of Venus.

Telescope.—12·6-inch clock-driven Calver equatorial.

Mr. A. F. Bennett's Observatory, Leiston, Suffolk

The 6-inch refractor has been used on the planets, including Mars at the last opposition. Observations of a number of variable stars and Nova Herculis 1934 have been continued and the results reported to the Variable Star Section of the British Astronomical Association.

The time determinations of six occultations of stars by the Moon observed during the year have been sent to the computing section of the B.A.A. for reduction and publication.

Wolsingham Observatory (Rev. T. E. Espin's), Tow Law, Co. Durham (Observer, W. Milburn)

The 24-inch (Calver) reflector was erected on the new site and brought into use on August 31.

The survey for new double stars in the zones $+35°$ to $+40°$ has been continued, together with the programme of remeasurement of certain known pairs, chiefly those of Espin and Milburn. The results have been communicated to the Society.

Mr. J. Evershed's Observatory, Ewhurst, near Guildford

Spectroheliograms in $H\alpha$ light for the estimation of character figures were obtained on 81 days and prominence plates on 79 days.

Seventy-four spectra of prominences were secured during the year, and these are being measured in continuation of the research on the solar rotation at high levels, and on the general shift of the calcium and hydrogen lines towards the red. This shift has always hitherto shown a considerable excess over the predicted relativity shift.

Photographs have been obtained of the spectrum of the Sun's limb in the red region with *Fe* arc comparison, both in the equatorial region and near the Sun's poles. Measures of these plates by the positive on negative method show quite definitely that the shift of the solar lines in this region of the spectrum is very nearly equal to the predicted relativity shift $\times 2$. This excess over the "Einstein effect" is an outstanding difficulty which cannot be ignored.

A new micrometer screw and self-centring nut have been obtained from Hilger, and the accuracy of the micrometer in measuring large intervals has been greatly increased by attaching the plate to be measured directly to the nut instead of to a carriage moved by the nut. This reduces friction to a minimum, abolishes "back-lash" and errors of run inherent in the carriage or its ways.

Mr. F. J. Hargreaves's Observatory, Kingswood, Surrey

The usual observations of the surface features of Jupiter were made, but owing to low altitude and adverse weather conditions only 220 central-meridian transits of markings were obtained. Twenty-five drawings of Mars were made. The figure of the 14·2-inch mirror has been further improved, and various structural alterations in the mounting have been made.

Dr. J. L. Haughton's Observatory, Teddington

During the early part of the year a considerable amount of time was spent completing the building of the observatory and fitting up and adjusting the telescope.

Thirteen lunar occultations have been observed during the year and a certain number of stellar photographs have been taken.

This being the first report from this observatory, its position is given below.

Lat. N. 51° 25′ 15″.
Long. W. 0° 19′ 20″·5.
Altitude, 13 metres.

Mr. F. M. Holborn's Observatory, Streatham Hill, London

Observations were made on 184 nights and 259 days during the year. Visual estimates of brightness of Nova Herculis were made on 149 nights. 1493 observations were made of 52 variable stars. Mars was observed with the $8\frac{1}{2}$-inch reflector on 18 nights and several drawings made.

The Sun was observed with the $3\frac{1}{2}$-inch refractor, loaned by the British

Astronomical Association, on 259 days, 19 of which were spotless. 195 whole disc and 8 large scale drawings of spots were made. A few meteor flights were recorded. All records of observations were sent to the appropriate sections of the British Astronomical Association.

Position of the observatory : Long. $+0^h\ 0^m\ 29^s{\cdot}12$.
Lat. $+51^\circ\ 26'\ 38''{\cdot}8$.
Altitude 53 metres.

Mr. Newbegin's Observatory, Worthing, Sussex

The year 1935 has witnessed a pronounced revival in solar activity, and the equipment of the observatory has been employed entirely on observations of the Sun.

The 6¼-inch refractor, with the 3-prism Evershed spectroscope, as in former years, has been used mainly for recording the positions, heights and densities of prominences appearing at the limb, and the 3-inch refractor for details of sunspots.

About 100 observations have been made with the spectrohelioscope in *Hα* light, chiefly in recording differences in radial velocities in dark flocculi connected with sunspots. Records have also been kept of the numbers and positions of both bright and dark flocculi appearing on the disc. The spectrohelioscope performs well, and the image is very steady and free from flicker and vibration.

Adverse weather conditions from August to December seriously interrupted the continuity of observations, and during that period a fall of no less than 26·21 inches of rain was recorded on 84 days.

The instrumental equipment of the observatory has been very greatly enhanced by the addition of a fine 9-inch equatorial *Coudé* telescope, which has been presented to me by the Hon. Mrs. Lionel Guest in memory of her husband, who died in September. Not being able to erect this telescope at "Starween," I have offered it on loan to Mr. Bernard Pitcher of Worthing. He will erect it in his garden, which is within five minutes walk of the observatory, and will use it for solar work and variable star observations.

A Synchronome clock, also a gift from the donor of the *Coudé* telescope, has been added, and I desire to place on record my appreciation of these munificent gifts.

Mr. B. M. Peek's Observatory, Solihull, Birmingham

Physical observations of the major planets, Mars, Jupiter and Saturn, have been carried on, Jupiter always claiming priority. Unfortunately the increasing southerly declination of the last named caused the number of spot transits recorded to fall to about 50 per cent. of the corresponding number for 1934.

Photometric observations of Nova Persei 1901 have been continued, while estimates of the magnitude of Nova Herculis 1934 were obtained on 146 nights during the year.

Nine occultations of stars by the Moon were recorded in 1935.

At the end of December a 12¼-inch Calver Mirror, recently refigured by Mr. F. J. Hargreaves and kindly lent by Rev. T. E. R. Phillips, was mounted in place of the 12¼-inch Linscott. Subsequent tests have shown its figure to be exceptionally perfect under normal observing conditions, and its performance to be exceedingly fine.

The Rev. T. E. R. Phillips's Observatory, Headley, near Epsom

The usual programme of work on double stars and the planets was continued, and determinations of the magnitude of Nova Herculis 1934 were made during the earlier part of the year.

With Jupiter so low in the sky there was a large drop in the number of spot transits observed, but much time was devoted by both observers to the observation of Mars, which was in opposition on April 6. Conditions of seeing were not particularly good, and the planet's diameter only reached 15″, but occasionally a considerable amount of detail was recorded.

An Interim Report of the B.A.A. Mars Section dealing with the recent apparition of the planet was published by Dr. Waterfield (*B.A.A.J.*, **45**, 347). A series of micrometric measures of Saturn's belts was made with the 8-inch refractor.

Preparation was made to photograph on January 8 the totally eclipsed Moon and full Moon on blue-sensitive and infra-red plates in order to determine their relative brightness and colour. The plan carried out during the eclipse of 1932 September 14 was to have been repeated in a somewhat modified form, but the weather prevented any observations.

Owing to work on Mars and other duties, Dr. Waterfield was only able to expose a few plates with the 6-in. Cooke triplet. Some long exposures, however, were made on Nova Herculis.

A short paper by Dr. Waterfield on the elimination of atmospheric refraction in the adjustment of an equatorial to the true pole is published in *B.A.A.J.*, **45**, 282.

Some slight irregularities in the figure of the 12¼-in. mirror have been completely removed by Mr. F. J. Hargreaves. The mirror is now on loan to Mr. Peek. Mr. Hargreaves has also improved the corrections of the O.G. of the Coleman Telescope by slightly separating the component lenses.

The Meteorological observations now cover twenty years. The mean annual rainfall is 32·14 inches. Despite the long drought in the summer of 1935 the subsequent heavy rain brought the total for the year to 39·39 inches.

Mr. F. J. Sellers's Observatory, Muswell Hill, London

The Sun has been observed on 226 days during the year and the usual drawings and records of sunspots, faculæ and prominences have been made and positions charted. Summaries have been communicated to the British

Astronomical Association in the quarterly Solar Activity Reports published in the *Journal*.

An experimental short focus spectrohelioscope has been mounted on the 5-inch equatorial, but, in the very limited opportunities for adjusting and testing since completion, only partial success has, so far, been attained.

A fixed instrument with 10-foot focus collimator and fed by cœlostat is now being constructed, using a Rowland grating kindly lent by Mr. Newbegin. It is hoped that this instrument will be in use during the summer.

Only four observations of lunar occultations have been possible. These have been reduced and communicated to the B.A.A.

Dr. W. H. Steavenson's Observatory, West Norwood

Observations were made on 182 nights during the year.

The 20½-inch Hindle reflector was used chiefly for the observation of faint variables and novæ. 264 observations of 20 long-period and irregular variables were made, and have been communicated to the Variable Star Section of the B.A.A. 314 observations of 13 novæ were also made, and some of the results have already been communicated to the Society.

A number of estimates of the relative brightness of the 4 satellites of Uranus were made during the year. It is hoped later to reduce these observations to the standard scale by means of a photometer.

Some physical observations of Mars were made during the Spring, and Johnson's comet was observed for position on 2 nights.

The mirrors of the telescope were resilvered in April and September.

NOTES ON SOME POINTS CONNECTED WITH THE RECENT PROGRESS OF ASTRONOMY

Minor Planets

The lettering gives approximately the date of discovery; in the first half of January the first letter is A, in the second half B, the first letter changing every half-month, I, J being treated as a single letter; December discoveries begin with X or Y.

Two hundred and ninety planets were discovered, or first announced, in 1935 as follows:—

S. Arend (Uccle) CA, CB, CC, CD, CE, CF, CG, CK, CL, CM, CR, CS, DA, DB, DC, DD, EB, EC, ED, EE; L. Boyer (Algiers) FB, FC, GA, OA, VB; R. Carrasco (Madrid) EM, WB, YA; E. Delporte (Uccle) BA, BB, BC, BD, BE, BF, BG, BH, CH, CJ, CN, CO, FA, FD, FE, FJ, JA, PA, PB, PC, QA, RA, SA, SB, SC, SD, SE, SR, SS, SO_1, UA, UB, UC, UD, WA; E. P. Hubble (Mount Wilson) QN; C. Jackson (Union Observatory, Johannesburg), 1934 NA, NB, NC, NG, NH, NV, NW, NX, NY, NZ, NA_1, NB_1, NC_1, VT, VU, VV; 1935 EN, EO, FM, FN, FO, FP, FQ, FR, FS, GB, GE, GF, GG, GH, GJ, GK, GL, GO, HB, HC, HD, HE, HF, HG, JB, JC, JD, JE, JF, JG, JH, JJ, JK, JL, JN, KC, KD, KE, ME, MF, MG, MH, NC, ND, OB, OC, OD, OE, OF, OG, OH, OJ, OK, OL, QP, QQ, QR, QS, QT, QU, QV, QW, QX, QY, QZ, QA_1, QB_1, QC_1, QD_1, QE_1, QF_1, QG_1, QH_1, RJ, RK, SN, SQ, ST, SV, SW, SX, SY, SZ, SA_1, SC_1, SD_1, SE_1, SF_1, SG_1, SH_1, SJ_1, SK_1, SL_1, SM_1, SN_1, TJ, UK, UL; Madame Laugier (Nice) FF, FG, FH; V. V. Lavdovsky (Simeis) TG; O. Melnikov (Simeis) NA; G. Neujmin (Simeis) BJ, CT, FJ, GC, LA, MD, NA, PA, PD; K. Reinmuth (Heidelberg) CP, CQ, DD, DE, DF, DG, DH, DJ, EG, EH, EJ, EK, EL, KA, MB, MC, QF, QG, QH, QJ, QK, QL, QM, RB, RC, RD, RE, SO; G. Reiss (Algiers) GA, MA, UH; F. Rigaux (Uccle) SF, SH, UG; P. Shajn (Simeis) QB, QC, QD, QE, RD, RF, RG, RH, SC, SJ, SK, SL, SM, TA, TB, TC, TD, TE, TF, TH; R. Suvanto (Turku) UE; Y. Väisälä (Turku) EA, FK, SG; G. van Biesbroeck (Yerkes) 1934 TM, UC, VR, VS, XH; 1935 EF, OM, SP; H. van Gent (Union Observatory, Johannesburg) 1934 JK, JL, JM, ND_1, NE_1, RV, RW, RX, RY, RZ, RA_1, RB_1, SB, SD, TN, VW, VX, VY; 1935 CU, CV, CW, CX, EP, EQ, ER, ES, GP; H. E. Wood (Union Observatory, Johannesburg) FL, HF, KB, PE, QO.

The following identities are announced and numbers assigned:—

220 = 1925 VE; 567 = 1935 UJ; 710 = 1934 LF; 715 = 1916*m*; 870 = 1907 AN*b*; 888 = 1906 UK = 1908 MF; 906 = 1903 MR; 913 = 1909 GX*a*; 930 = Σ20; 931 = 1904 OB; 936 = 1913 RH = 1921 LC; 946 = 1911 LZ*a*; 981 = 1906 VG; 1017 = 1929 LG; 1018 = 1926 VK; 1032 =

1917 BL = 1934 SA; 1137 = 1908 BY; 1271 = 1930 MK; 1292 = 1907 YH = 1932 KG; 1294 = 1930 AF; 1302 = 1924 SV = 1930 WD; 1303 = Σ84 = 1926 XD; 1928 FP = 1928 HH; 1304 = 1928 KC = 1934 LE; 1305 = 1928 OC = 1932 FA = 1933 MB; 1306 = 1930 OB = 1935 OA; 1307 = 1930 UF = 1933 QF_1; 1308 = 1931 EB = 1933 SP; 1309 = 1919 GG = 1931 TO = 1934 GT; 1310 = 1932 DB; 1311 = 1916 AU (probably) = 1929 CG_1 = 1933 FF_1; 1312 = 1933 OT; 1313 = 1911 MF*g* = 1933 QG; 1314 = 1933 SC; 1315 = 1905 SB = 1933 SF_1; 1316 = 1933 WC; 1317 = 1934 FD; 1318 = 1934 FG; 1319 = 1908 CK = 1934 FO; 1320 = 1934 JG; 1321 = 1934 JH; 1322 = 1934 LA; 1323 = 1911 LU = 1934 LD; 1324 = 1934 LL; 1325 = 1934 NR; 1326 = 1934 NS; 1327 = 1934 RT; 1328 = 1925 UA; 1329 = 1933 FL; 1330 = 1925 DB = 1933 QK_1; 1331 = 1926 FD = 1928 TH = 1933 QS; 1332 = 1934 AA = 1935 FR; 1333 = 1934 DA; 1334 = 1934 OB; 1335 = 1934 RE; 1336 = 1929 QE = 1932 EM = 1934 RW; 1337 = 1934 RA_1; 1338 = 1934 XA; 1339 = 1934 XB; 1340 = 1934 YA; 1341 = 1935 BA; 1342 = 1935 CV; 1343 = 1935 FC; 1344 = 1935 GA. The numbers from 1302 to 1344 are new.

Of the unnumbered planets 1898 DW = 1931 VW; Σ58 = 1935 OB; Σ95 = 1928 QJ = 1934 TF; 1923 NV = 1929 VJ = 1934 RV; 1925 WF = 1934 RW; 1926 FD = 1928 TM = 1933 QS; 1928 RK = 1932 WL; 1930 KD = 1931 TO_2; 1930 OB = a planet observed on 1933 February 19, which was at first wrongly identified with No. 386; 1930 SK = 1933 DF; 1930 UF = 1933 QF_1; 1931 JD = 1933 SM_1; 1931 TU = 1934 GT; 1932 DB is not identical with 330, as was previously thought; 1932 WA = 1935 GM = 1935 JM; 1934 LJ = 1934 NA.

The following identities are considered probable: 710 = 1934 LF; 854 = 1935 QE; 962 = 1935 MF; 963 = 1931 TE_3; 1311 = 1916 AU; 1933 FD = 1934 LG; 297 possibly = 1935 PB.

The new planet 1935 QN (Hubble) has an interesting orbit: *Harvard Circ.*, 351, gives the following elements by Dr. Paul Herget :—

T	1935 November 14·9612 U.T.	q	2·321123
ω	99° 16′ 20″	a	3·409523
Ω	297° 50′ 58″ 1935·0	e	0·319223
i	38° 51′ 43″	Period	6^y·29565

The inclination is exceeded only by that of 944 Hidalgo, which was 43° 4′ in 1920. Hidalgo was well observed in 1935, but will probably not be seen again till it approaches perihelion about 1948.

The following planets have been named: 991 McDonalda (altered from Donalda); 1058 Grubba; 1153 Wallenbergia; 1205 Ebella; 1206 Numerowia; 1207 Ostenia; 1209 Pumma; 1246 Chaka; 1248 Jugurtha; 1255 Schilowa; 1264 Letaba; 1268 Libya; 1278 Kenya; 1279 Uganda; 1287 Lorcia; 1295 Deflotte; 1296 Andrée; 1301 Yvonne; 1308 Halleria; 1312 Vassar; 1313 Berna; 1314 Paula; 1315 Bronislawa; 1318 Nerina; 1319 Disa; 1329 Eliane; 1335 Demoulina; 1341 Edmée.

A very important volume has been published by the Berkeley Astro-

nomical Department under the direction of Professor A. O. Leuschner; it forms vol. xix of the *Publications of the Lick Observatory*. It is a sequel to the *Research Survey of* 21 *Minor Planets* published by the National Academy of Sciences in 1922. The Cambridge Meeting of the International Astronomical Union (1925) urged the extension of these surveys. The International Education Board gave a grant to help the work, which was originally under the direction of Professor H. Thiele. The present volume contains a summary of all the work done on planets No. 1 to No. 1091 up to the year 1929. The introduction explains various methods that may be used to improve the orbits; in some cases general perturbations can be developed; others depend on the calculation of special perturbations. Particulars are given of the discovery of each planet, with a summary of the work that has been done on its orbit. These are naturally more extended for the older planets, and for objects of special interest such as Eros and the Trojans.

A.N., No. 6107, contains an interesting article by Dr. G. Stracke on the work of the Rechen-Institut during the last twenty-five years; with the help of about twenty co-operating observatories an efficient watch is kept upon the great army of planets, and their orbits are also calculated, and revised when necessary. A list of the first 1301 planets follows, with the dates of discovery and the number of oppositions at which each has been observed. Observers should consult this list, which indicates the planets that specially need observation. A. C. D. C.

Comets

Three new comets and one expected periodic comet were detected in 1935; also Reinmuth's periodic comet, detected in 1934 November, and comet 1929 I (Schwassmann-Wachmann (2)), detected in 1934 December, passed perihelion in 1935. Only one of the three new comets passed perihelion in 1935; the other two pass it in 1934 and 1936 respectively. Thus 1934 is no longer blank as regards perihelion passages of unexpected comets.

Comet 1935 *a* was discovered photographically on January 7 by Mr. E. L. Johnson at the Union Observatory, Johannesburg; it was in decl. $-51°$, but was moving rapidly northward, becoming visible in Europe in February, when its magnitude was 9; it was followed till May 24; Professor van Biesbroeck gave its magnitude on May 11 as 17. There were numerous observations during February, March and April; the declination reached 81° N. on May 10; the orbit proves to be elliptical, Dr. M. Davidson finding a period of 930 years, and Dr. A. D. Maxwell, from a longer arc, one of 900 years. Dr. S. Vsessviatsky investigated the comet's spectrum at Moscow, obtaining strong images at λ 3880 and λ 4710, and weaker ones at λ 4390 and λ 4100; there was also a large carbon image; the continuous spectrum was weak (*U.A.I. Circ.*, 526). *P.A.* for April reproduces a photograph of the comet, taken at Yerkes by Professor G. van Biesbroeck with the 24-inch reflector on February 27; it shows a circular head, about 4′ in diameter; the main tail was about 20′ long, with fainter lateral streamers.

Comet 1935 *b* was discovered photographically on June 3 by Mr. C.

Jackson at the Union Observatory, Johannesburg. It proved to have passed perihelion in September 1934; it was nearly $4\frac{1}{2}$ units from the Sun when discovered, and approached Jupiter within 0·835 unit on 1935 October 27.

Professor G. van Biesbroeck observed the comet during the lunar eclipse on July 16, also on July 21, when it was round and diffuse, about 10″ in diameter, magnitude 16. That is the latest observation to hand.

Comet 1935 *c* is the periodic comet 1927 III (Comas Sola); it was detected by Dr. Jeffers at the Lick Observatory on August 12. Professor van Biesbroeck then found faint images on plates of August 9 and 11; it was described as diffuse, 18″ in diameter, with a short tail $1\frac{1}{2}'$ long, pointing westward, magnitude 14. Definitive elements for the apparition of 1927 were deduced by Miss Vinter-Hansen; the perturbations from 1927 to 1935 were worked out in duplicate, as an example of certain methods, and are printed in the Nautical Almanac publication *Planetary Co-ordinates for the Equinox of* 1950. The observations of 1935 show that *T* is near 1935 October 6·6, which is $1^{d}\cdot7$ earlier than the prediction. The comet is still under observation.

B.A.A. Journ., **45**, No. 6, contains an article by P. Ramensky on the past history of this comet; he adopted Miss Vinter-Hansen's value of the period in 1927; as this appears to be too great by $1^{d}\cdot7$, his results need a slight adjustment. His special object was to investigate the near approach of the comet to Jupiter in May 1912, the least distance from Jupiter being 0·19. The comet's period before 1912 was $9^{y}\cdot43$, which would indicate another near approach to Jupiter in 1865. Mr. Ramensky's work disproves the suggested identity of comets Spitaler and Comas Sola.

Comet 1935 *d* was photographically discovered by Professor G. van Biesbroeck at Yerkes Observatory on August 21; it was a diffused object of magnitude 14; it was within 8′ of an asteroid for which the plate was being exposed. Its motion was slow, owing to its considerable distance from the Sun and the Earth, and early attempts to calculate the orbit were very discordant; it was eventually found that the comet does not reach perihelion till May 1936, its perihelion distance being more than 4 units. At the end of the year it disappeared, being lost in the Sun's rays, but it should be recovered in the spring. Five prediscovery images were found on plates exposed at the Union Observatory, Johannesburg, on July 3, 22, 29 and August 5 (two images) (*U.A.I. Circ.*, 564).

The last annual report mentioned the detection of two periodic comets in the autumn of 1934, which did not reach perihelion till 1935. Observation of these was continued in the early months of 1935; both remained faint, the magnitudes being 14 or 15. They were observed by Dr. Jeffers, Professor G. van Biesbroeck and Professor Schorr. Dr. Jeffers also observed comet 1933 *f* (Whipple) up to 1935 March 28, when its magnitude was about 19. Reinmuth's comet was observed till April, when it was in perihelion, but still remained faint. Comet 1929 I, Schwassmann-Wachmann (2), was observed till February 27, then lost in the Sun's rays and not recovered till November 23, when its magnitude was 14·5. It then had a nucleus and a short tail. Mr. H. Q. Rasmusen has made a careful study of

the past history of this comet in *Publication No.* 106 of Copenhagen Observatory. He corrected the mean motion by the recent observations, and carried the calculation back to 1920 ; the distance from Jupiter fell to 0·179 on 1926 March 26 ; for seven years, from 1921 March to 1928 March, the comet was within 2 units of Jupiter ; the orbit in 1921 was considerably larger than the present orbit ; the period was then 9·3 years ; it is now 6·4 years.

Four other periodic comets, for which search ephemerides were published in the *B.A.A. Handbook* for 1935, were unsuccessfully sought for

Table

Comet	*T*	ω	Ω	*i*	*q*
		° ′ ″	° ′ ″	° ′ ″	
1913 III Neujmin (1)	1913 Aug. 16·4749	346 14 40	347 53 46	14 50 19	1·52879
1931 I Neujmin (1)	1931 Apr. 30·0767	346 57 51	347 18 55	15 8 54	1·52791
Schw.-Wach. (2)	1920 May 9·56	335 27 43	126 40 52	0 42 36	3·5538
1935 *b* Jackson	1934 Sept. 6·9205	124 17 59	73 17 33	141 56 52	3·48579
1935 *a* Johnson	1935 Feb. 26·46876	18 23 16	91 32 35	65 25 34	0·81114
1934 *c* Reinmuth	P 1935 May 1·42	8 50 9	124 57 57	8 4 2	1·87131
	Obs^{d}. May 1·8				
1934 *d* Schw.-Wach. (2)	1935 Aug. 28·55038	357 58 17	126 17 30	3 43 43	2·09482
1935 *c* Comas Sola	P 1935 Oct. 8·383	38 47 10	65 42 29	13 43 19	1·77726
	Obs^{d}. Oct. 6·6				
1935 *d* van Biesbroeck	1936 May 6·4772	43 36 23	299 39 23	66 28 38	4·09038
1948 Neujmin (1)	P 1948 Dec. 19·1296	346 44 44	347 13 15	15 1 46	1·54441

in 1935 ; they were 1927 VIII, Schaumasse ; 1930 VI, Schwassmann-Wachmann (3) ; 1929 II, Forbes ; 1930 VIII, Tempel (2) ; they were all inconveniently near to the Sun at the time of greatest brightness.

In view of the fact that the orbit of comet 1930 VI makes a very near approach to the Earth's orbit (see *U.A.I. Circ.*, 537, 540, 541), a search was made last June for possible meteors moving in orbits near that of the comet ; Professor O. Thomas (Vienna) saw a few meteors on the night June 8–9 that came from the computed radiant ; but there was no rich shower.

Comet Schwassmann-Wachmann (1), 1925 II, was again under observation during 1935 ; on March 27 Professor G. van Biesbroeck exposed a plate which showed stars to magnitude 17·5, but the comet was invisible ; on April 7 it had risen to magnitude 15, most of its light being concentrated within a radius of 10″ ; on May 4 it was a small round coma of magnitude 12·5 ; on May 14 its magnitude was 14·5. Similar changes of brightness have occurred nearly every year since its discovery in 1927.

Copenhagen Obs. Pub., No. 98, contains a study by Professor E. Strömgren and Mr. H. Q. Rasmusen of the original orbit of comet 1907 I (Giacobini) which had a hyperbolic orbit at perihelion ; but, on carrying the perturbations back to 1890, when the distance from the Sun was 35 units, the orbit was found to be elliptical ; a similar result has been reached in all cases where there was enough material to deduce reliable orbits.

No. 105 of the same *Publications* contains a similar study of comet 1904 I (Brooks). Here, too, the orbit was hyperbolic at perihelion but was shown to be elliptical fourteen years earlier ; it was further shown that it was constantly elliptical before that date.

Volume 25 of *Results of Cordoba Observatory* (Argentine) consists of an important memoir on the 1910 apparition of Halley's Comet, by the Director, Professor C. D. Perrine. Ninety-nine photographs of the comet are reproduced, their dates ranging from April 17 to July 6, 1910 ; they show the rapid changes in the appearance of the tail in May ; the tail was shown

net Orbits

Period	Equinox	Computer	Reference	Comet
y				
·7671	1913·0	G. van Biesbroeck	*A.J.*, 1029	1913 III.
·6871	1931·0	G. van Biesbroeck	*A.J.*, 1029	1931 I.
·3117	1950·0	H. Q. Rasmusen	*Copⁿ. Obs. Pub.*, No. 106	Schw.-Wach. (2)
...	1935·0	H. E. Wood	*U.A.I. Circ.*, 547	1935 *b*.
900y	1935·0	A. Maxwell	*U.A.I. Circ.*, 562	1935 *a*.
·32060	1935·0	J. T. Foxell and A. E. Levin	*B.A.A. Handbook*, 1935	1934 *c*.
·424424	1950·0	H. Q. Rasmusen	*Copⁿ. Obs. Pub.*, No. 106	1934 *d*.
·5397	1950·0	Miss J. M. Vinter-Hansen	*Copⁿ. Obs. Pub.*, No. 85	1935 *c*.
...	1935·0	H. E. Wood	*U.A.I. Circ.*, 562	1935 *d*.
9317	1950·0	G. van Biesbroeck	*A.J.*, 1029	1948.

to have two branches at the time that it was near the Earth ; it is concluded that the Earth did not pass through the main tail, but it may have traversed the fainter southern branch ; the maximum brightness of the comet, magnitude 0·4, was attained on May 13. The volume contains 64 visual determinations of the position of the comet and 59 photographic ones. The positions of the comparison stars are discussed.

At the Paris Meeting of the International Astronomical Union, Commission 20 appointed a sub-committee, of which Miss Vinter-Hansen of Copenhagen Observatory was nominated Secretary ; the work of the sub-committee is to arrange for the calculation of orbits and ephemerides of periodic comets, thus to ensure that such comets shall not be overlooked at their return, and to avoid unnecessary duplication of calculations. Anyone who proposes to undertake such calculations, or who is already engaged upon them, is requested to communicate with the Secretary.

A. C. D. C.

Solar Activity

Sunspots.—The year under review was one of increasing activity in solar phenomena represented by sunspots and faculæ, bright and dark flocculi

and prominences. The frequency of bright *Hα* eruptions and of radial velocities near sunspots also showed a marked increase.

The mean daily area of sunspots rose from 119 millionths of the Sun's hemisphere in the year 1934 to approximately 550 millionths in 1935. The average daily number of spots has likewise shown a significant increase, and on a few occasions as many as ten groups were visible at one time. Large spots are becoming more frequent, and a group reaching an area of nearly 2500 millionths made its appearance recently (November 26 to December 9).

The following groups of sunspots, designated by their respective times of central meridian passage and their latitudes, exceeded 500 millionths of the Sun's hemisphere for at least a few days :—

(1) Feb. 4·6	−17°	(6) Oct. 26·4	+20°
(2) June 2·2	−30°	(7) Nov. 9·5	−30°
(3) June 29·9	−24°	(8) Nov. 13·2	+21°
(4) Aug. 19·6	+28°	(9) Dec. 2·1	−25°
(5) Oct. 21·0	+23°	(10) Dec. 12·5	−23°

Groups Nos. 1, 3, 7 and 9 each exceeded 1000 millionths in area at their observed maximum development ; Nos. 1 and 4 (see *P.A.S.P.*, **47**, 272, 1935) were notable for their unusually rapid rate of growth ; No. 1 originated on February 6 after the date of its central meridian passage. No. 6 represents two closely adjacent groups combined. Bright *Hα* eruptions were observed on one or more occasions in association with spots Nos. 3, 4, 5, 6, 8 and 9. A number of other *Hα* eruptions associated with smaller groups were observed at Greenwich and are recorded in *Solar Notes* published monthly in *The Observatory*, whilst a complete list of such eruptions observed by international co-operation is being collected by d'Azambuja for publication in the quarterly *Bulletin* issued from Zurich. The observations of radial velocities of dark *Hα* flocculi associated with sunspots during 1935 are too numerous to be listed here, but the more important of them receive comment in *Solar Notes* (*loc. cit.*), and the individual observations will be published in the *Greenwich Photoheliographic Results* for 1935. The largest velocity recorded at Greenwich during the year was −125 km./sec. in association with a sunspot in latitude −30° and central meridian passage on May 4·3 ; the associated phenomena and their significance, as representing one of two allied types of chromospheric eruptions, are described in *M.N.*, **95**, 650, 1935.

During the year 8 minor terrestrial magnetic storms (D ⩾ 30′ or H or V ⩾ 150 γ) were recorded at the Greenwich station at Abinger. Of these 8 magnetic disturbances, only 1 coincided with the central meridian passage, or within 4 days of the passage, of a large spot (No. 5) listed above ; in 6 other cases there was a small or moderate-sized spot within the prescribed limits of position on the disc, and in one case, that of the storm commencing September $10^{d}\cdot7$, there was no spot present near the centre of the disc.

H. W. N.

Prominences 1935.—With the advance of the new cycle, there has been a further increase in all forms of prominence activity during the year. The

mean daily areas and numbers of calcium prominences as derived from Kodaikanal spectroheliograms are as follows :—

Areas

	North	South	Total
1935 January to June ...	... 2·01	2·50	4·51 sq. mins. of arc.
July to December ...	... 2·54	2·61	5·15 „ „

Numbers

	North	South	Total
1935 January to June ...	... 6·80	6·86	13·66
July to December ...	... 6·67	6·58	13·25

Calcium areas and numbers show an increase of 26 per cent. and 2 per cent. respectively over the previous year. The southern hemisphere shows a slight preponderance of activity over the northern. The distribution in latitude shows a maximum of activity near latitude 50°, which is 5° nearer the poles than in 1934.

Twenty metallic prominences were observed during 1935, as against 8 in the previous year. Of these, 3 were observed in the northern hemisphere and 17 in the southern hemisphere, between the latitudes 17° and 34° from the equator. Displacements of the hydrogen line in the chromosphere and prominences observed during the year numbered 174, as against 137 observed in 1934. Of these, 99 were towards the red, 66 to the violet and 9 both ways simultaneously.

Bright reversals and displacements of the *Hα* line observed on the disc in the neighbourhood of sunspots also show a considerable increase over the previous year. Bright reversals numbered 369 as against 118 in 1934. The displacements observed numbered 28, while the number observed in the previous year was 14. Of these, 12 were towards the red, 7 towards the violet and 9 both ways simultaneously. D_3 was observed as a dark line on 303 occasions as against 106 in the previous year.

The mean daily areas of prominences projected on the disc as hydrogen absorption markings amounted to 4447 millionths of the Sun's visible hemisphere, as against 1990 during the previous year, showing an increase of 123 per cent. Their distribution in latitude is similar to that of calcium prominences, with the difference that the peaks of activity are more emphasised than in the latter, so that a secondary maximum of activity near 30° stands out in the former distribution. T. R.

Spectrophotometry

Spectrophotometry of the Continuous Spectrum.—D. Barbier, D. Chalonge and E. Vassy (*Journal de Physique*, 1935 April) have studied the distribution of energy in the continuous spectrum of some selected stars throughout the spectral range λ 3000 to λ 4500. The observations were taken at Jungfraujoch (altitude 3457 metres), the comparison source of light being the hydrogen tube developed by Chalonge and Lambrey. The continuous

spectrum of molecular hydrogen emitted by the tube when excited by 9 milliamperes at 1000 volts was standardised by comparison with a standard lamp. The optical train employed was an objective prism arrangement (consisting of two 30° prisms, these being the two halves of a Cornu prism) in conjunction with a quartz objective. The axis of the objective was tilted so as to broaden the spectrum by astigmatism. The hydrogen tube was placed at the focus of a collimator with a quartz objective and the plates were calibrated by the use of diaphragms placed over the collimator objective, the same exposure time being maintained over the whole of each plate.

Results are given for 17 stars. In all of these the discontinuity at the head of the Balmer series is well exhibited, the spectrum to the violet side of the head being depressed except in the case of γ Cassiopeiæ for which there is continuous Balmer emission beyond the head instead of the usual absorption. The authors derive colour temperatures from their results over the wave-length range λ 3700 to λ 4500. A comparison with the Greenwich results is of interest. For 12 stars of spectral types B and A, which have also been observed at Greenwich, the mean value of c_2/T ($c_2 = 14320$) obtained from the results of Barbier, Chalonge and Vassy is 0·84. The corresponding Greenwich value (based on the revised value for the zero point, viz. $\phi = 1{\cdot}0$, $c_2/T = 0{\cdot}8$ for the mean of certain Ao stars *) is 0·78. The difference of 0·06 is within the probable error of an absolute series of colour temperature observations, and the results may be said to be in accord.

G. F. W. Mulders (*Zs. f. Ap.*, **11**, 2, 132, 1935 December) has applied his calibration of the Rowland intensity scale to the determination of the energy distribution in the continuous spectrum of the Sun. The calibration gave, for each Rowland intensity, the equivalent breadth in angstroms as a function of wave-length. These results were used to derive the intensity of the continuous spectrum from Abbot's measures which, it will be remembered, included the absorption lines. The observations of H. H. Plaskett, some of which were affected by absorption lines, were also corrected where necessary. The corrected results both of Abbot and Plaskett are in excellent agreement and show that between λ 4000 and λ 7000 the distribution of energy at the centre of the disc is that of a black body at a temperature of 7140° K. In other words, the colour temperature of the centre of the disc between these wave-lengths is 7140°. This result may be compared with the Greenwich value of 6800° for the mean of the dwarf Go stars (*M.N.*, **94**, 6, 507). The latter result refers, of course, to the integrated disc and would correspond to about 7200° for the centre of the disc.

Mulders also attempts to correct the measures of Fabry over the spectral range λ 3000 to λ 4000. For wave-lengths below λ 3850 no calibration of the Rowland scale was available, and the calibration for λ 3900 was used. The results for the region are thus comparatively uncertain. Such as they are, they give a colour temperature of 4850°.

Mulders also determines the fraction η absorbed by the reversing layer

* *M.N.*, **94**, 6, 507.

from the total energy of the Sun's continuous spectrum. His result is $\eta = 0{\cdot}083$. He also applies his results to the calculation of the absorption coefficient as a function of wave-length.

A. Pannekoek (*M.N.*, **95**, 6, 529, 1935 April) applies his theoretical values of the absorption coefficient as a function of wave-length to the calculation of theoretical colour temperatures. He gives colour temperatures at wave-lengths λ 4500 and λ 5500 for stars of different effective temperatures. For stars of effective temperature 20,000°, Pannekoek's colour temperatures are practically identical with the effective. But as the effective temperature falls from 20,000° to 10,000°, the colour temperature remains practically stationary. For still lower effective temperatures the colour temperature falls rapidly, and overtakes the effective at about 7000°. For still lower effective temperatures the colour temperature is lower than the effective. For an effective temperature of 5740° (that of the Sun), Pannekoek's theoretical colour temperatures are well below 5000°.

This last circumstance alone shows that there is something wrong with the theory as it is in direct conflict with observation. It would appear that the absorption coefficients derived from Kramer's theory, on which the calculations are based, are erroneous and in point of fact for $T_e = 5740$ (the Sun) Pannekoek's absorption coefficients are in definite disagreement with those obtained by Mulders (see above). A further possible source of error is the identification of the "temperature" T in the ionization formula with the effective temperature T_e of the star. Nevertheless, the investigations of this kind which have been performed by Biermann (*Gött. Nachr.*, 45 and 49, 1933), Unsöld (*Zs. f. Ap.*, **8**, 225, 1934), and now Pannekoek, are of importance, as they indicate the possibility of large differences between the effective and colour temperatures of a star.

Results for Nova Herculis 1934 are beginning to appear. F. Beileke and O. Hachenberg (*Zs. f. Ap.*, **10**, 5, 366, 1935 October) give energy distributions in the continuous spectrum for 16 dates between 1935 January 29 and 1935 April 2. The measures extend from λ 3600 to λ 6200, and to the redward of λ 4000, the continuous spectrum of the nova approximates to a Planck curve to within an accuracy of 10 per cent. The colour temperatures derived from this spectral range vary from 9800° on February 6 to 17,900° on April 2, these values being based on an assumed value of 11,500° for γ Ursæ Minoris. But in the ultra-violet for wave-lengths less than 4000 A. the continuous spectrum of the nova rises sharply in excess of the Planck curve.

Barbier, Chalonge and Vassy (*C.R.*, **201**, 2, 128, 1935 July) give energy distributions in the continuous spectrum of Nova Herculis 1934 for five dates extending from 1934 December 31 to 1935 March 6. Their measures extend from λ 3050 to λ 4900 and they find for the earlier dates a pronounced "hump" centering at about λ 4500. This hump appears to diminish as the nova develops and is comparatively feeble on the curve for March 6. This feature does not appear to be confirmed by the observations of Beileke and Hachenberg referred to above.

As regards routine colour temperature observations of stars, S. L.

Thorndike (*Harvard Bulletin*, 897) has given results for 25 stars of spectral types Bo to Ma.

Turning to special problems, B. Lindblad (*Stockholm Observatory Annals*, **12**, 2, 1935) has investigated a striking depression in the continuous spectrum of a dwarf star of spectral type M2. The star in question was Boss 2935 of absolute magnitude 10·7, and it is probable that the results are applicable to all dwarf stars of type M. The investigation consisted of a spectrophotometric comparison with a giant star of type M2 (Boss 2935 ; abs. mag. −0·5), and the results exhibit the depression in the continuum of the dwarf which extends from the *Ca* line λ 4227 in both directions, but especially towards the longer wave-lengths. The depression can be traced from about λ 4120 to λ 4650. Lindblad recalls the observations of Hamada (*Phil. Mag.*, **12**, 50, 1931), who found in emission a continuous spectrum around λ 4227 and extending from λ 3980 to λ 5100. Its presence in his laboratory observations was attributed by Hamada to a quasi-molecule of *Ca* which in the excited state consists of one atom in the $4s^1S_0$ level and one in the $4p^1P_1^0$ level.

Lindblad also tabulates the lines in the spectra of the two stars which can be readily identified. He gives values for the line intensities. Marked luminosity effects appear. For example, the *Ca* lines at λ 4425–4435 and at λ 4455 (belonging to the multiplet 4^3P^0–4^3D) are stronger in the giant. The majority of the lines tabulated are more intense in the dwarf.

Plate Calibration.—W. M. H. Greaves (*Observatory*, 740, 11, 1936 January) describes the results of a set of observations taken for the purpose of checking the calibration of the Greenwich plates. The stellar spectra are photographed with a 36-inch reflector and slitless spectrograph, and are calibrated with a multiple slit spectrograph, using a standard exposure time of 20 seconds. The stellar spectra were broadened by an electric motor and cam, the period of the complete double stroke being 5 seconds. The check observations consisted in photographing the spectra of stars with half and full apertures on the telescope and calibrating the plates as usual. The results showed that the characteristic curves derived from the calibration exposures were not directly applicable to the telescope exposures and correcting factors were derived. These factors varied with the exposure time on the telescope, showing that as far as the telescope exposures were concerned, the characteristic curve depended on the exposure time. The range of exposure times was 20 to 540 seconds.

In the Greenwich work the plates used were Ilford "Hydrogen Alpha" plates which were developed for 10 minutes in dilute pyro-soda at 60° F. A similar effect had been previously found for Imperial Panchromatic B plates, also developed in dilute pyro-soda at 60° F. But time effects of this kind are not always measurable, as is shown by the observations of R. O. Redman (*Observatory*, 731, 127, 1935 April), who, using Ilford ordinary Process plates, found no detectable change of characteristic curve over a range of exposure times 0·5 to 15 minutes. It is thus suggested that the magnitude of effects such as this depends on the emulsion used and possibly on the mode of development.

W. M. H. G.

Spectrophotometry of Line Contours.—Work has been carried out at the Solar Physics Observatory, Cambridge, on the use of the monochromator in determining the contours of Fraunhofer lines. While some investigators have computed the amount of light of an alien wave-length which makes its way into a Fraunhofer line on account of bad performance by the spectrograph used, and have allowed for it, it seems preferable to eliminate light of all wave-lengths except those in the immediate neighbourhood of the line to be examined by dispersing the sunlight, selecting a narrow range of wave-lengths and allowing only these to enter the slit of the spectrograph. A device of this kind is described by Redman (*M.N.*, **95**, 290, 1935), and observations made with it are described by Thackeray (*M.N.*, **95**, 293, 1935) and by Redman (*M.N.*, **95**, 742, 1935). Thackeray measured the lines $H\alpha$, $H\beta$, 4383 A., 4226 A., 4046 A., and Ca^+ K, finding in every case a lower central intensity of the line with the monochromator than without it. Redman measured very carefully the contour of the line 4226 A., *Ca*, and found for this line a central intensity of 2 per cent. of the intensity of the continuous background with a probable error of 1 per cent.

A freak observation of line contour is described by Woolley and Newton (*M.N.*, **96**, 5, 1935), who put the spectrohelioscope to this unusual use. This observation may lead to the development of accurate visual methods of determining line contours. Shane's interferometer method of determining line contour has been used by Cherrington (*Lick Obs. Bull.*, **17**, 161, 1935), who examined the Magnesium *b* group and finds that the equivalent breadths are not in the expected ratio $\sqrt{5} : \sqrt{3} : 1$. A fair amount of work has been done by the straightforward method of photography. An important volume of Fraunhofer Intensity Tables (*Memoirs of the Commonwealth Solar Observatory*, **5**, parts 1 and 2, 1934) was published by Allen, who surveys the solar spectrum from 4036 A. to 6600 A., and thus presents the largest homogeneous collection of such results which has yet appeared. A review of Allen's work and a comparison among all observers was published by Woolley in *The Observatory* (**58**, 329, 1935). Mulders has published an important calibration of Rowland's scale of intensities in the solar spectrum from 3900 A. to 8600 A. (*Zs. f. Ap.*, **10**, 297, 1935). Righini compares twenty-four members of the *Na* doublet spectrum with oscillator strengths calculated by himself (*Zs. f. Ap.*, **10**, 323, 1935). Agreement between theory and observation is obtained by a choice of damping constant 3·1 times the classical value. On the other hand, Minnaert and Genard are unable to reconcile observation with theory in the case of the $2P$–nD series of *Mg*. The weaker members of the series appear too strong, and in fact the f values computed from the observed equivalent breadths either are constant or actually increase with the serial number. The authors conclude that "this improbable result does not appear to be explicable by the known causes of line broadening"—in particular, they examine the Stark effect, which is not able to reconcile theory with observation.

The relative f-values for lines of *Fe*I from electric furnace absorption spectra have been determined by R. B. King and A. S. King (*Ap. J.*, **82**,

377, 1935). A furnace absorption spectrum is clearly the only laboratory spectrum in which the atoms are likely to be partitioned among their stationary states in a predictable manner; the authors of this work verify the predicted (Boltzmann) distribution by operating the furnace at different temperatures and checking the results. Within the multiplets the intensities agree with theory: these observations establish the relation between one multiplet and another in intensity. Allen, on the other hand, finds a discrepancy between observation and theory in some iron arc multiplet intensities (*M.N.*, **96**, 145, 1935). He finds that measured arc intensities agree with solar intensities better than either agree with theory in the case of some *Fe* multiplets in the yellow.

Some interesting work on the appearance of lines in emission within the broad H and K lines near the limb of the Sun and on the appearance of a bright line at 4511 A. in certain stars has been published by Thackeray (*Ap. J.*, **81**, 338 and 467, 1935), who accounts for both phenomena by considering carefully the atomic transitions involved. The central intensities of the Fraunhofer lines have received attention on the theoretical side from Strömgren (*Zs. f. Ap.*, **10**, 237, 1935) and Pannekoek (*M.N.*, **95**, 725, 1935). Both these writers support the notion that the central intensities may be due to cyclical fluorescent atomic processes involving electron captures. R. v. d. R. W.

Stellar Spectroscopy.

Bright-Line Stars.—A detailed study of P Cygni, made by O. Struve (*Ap. J.*, **81**, 66) with the purpose of testing the theory of an expanding nebular shell, suggests that this star has a nucleus of effective temperature 20,000° K surrounded by a shell, expanding with an outward acceleration, in which both emission and absorption lines originate. The absorption lines are characteristic of a higher level of excitation than the emission lines, the former corresponding roughly to type Bo–B1 and the latter to B2–B3. Elements of high ionization potential are found to originate at greater depths in the shell than those of low ionization potential, in conformity with the conclusions previously reached by Beals (*Obs.*, **57**, 319, 1934). The mechanism of line excitation deviates from thermal excitation, and the presence of a strong line at 4396 A. (agreeing in position with an *O*II line) suggests the possibility of cases of abnormal fluorescence.

Gerasimovič (*Obs.*, **58**, 115) suggests a preliminary hypothesis concerning the nature of Be spectrum variables which requires a series of detached expanding shells, starting and dissipating at regular intervals. Many of the well-known types of spectrum variation can be explained by assuming differences in the durations of the cyclical process and in the velocities of expansion.

The spectrum of γ Cassiopeiæ has undergone some unusual changes both in the emission and absorption lines. Lockyer (*M.N.*, **95**, 520) has shown that after the red components of the double hydrogen emission lines vanished, early in 1934, the remaining single emission lines moved from the positions normally occupied by the violet components to those of the

red components, and that later new faint violet components appeared—a sequence of events never previously observed in any star of this type. Observations by J. F. Heard (*Ap. J.*, **81**, 341) give wave-lengths and identifications of 34 emission lines in the visual region of the spectrum. His observations of the emission intensity ratios for the components of hydrogen lines are in conformity with Lockyer's, since he found strong violet components during 1933 and very strong red components in 1934 November. Lockyer (*M.N.*, **96**, 2) has also announced the appearance of a new absorption line at approximately 3888 A., which is possibly due to the *He*I line 3888·646 A. The new line is very strong and sharp, being one of the most conspicuous features of the spectrum.

Variations in the bright hydrogen lines of β Piscium are noted by Shajn (*Pulk. Circ.*, No. 13), who also announces the star H.D. 162428 (mag. 7·01, spectral type A0) to be a new B9e star.

Five faint stars (mags. 8·4 to 9·0) have been discovered by Neubauer (*Pub. A.S.P.*, **47**, 59) to have spectra of class Be.

Radial Velocities.—Sanford (*Ap. J.*, **82**, 202) has measured the radial velocities of a number of stars of types N and R. He gives a catalogue of 191 results, which embodies values previously obtained from other sources and is complete as regards our knowledge of the velocities of these carbon-band stars. Those which have emission lines of hydrogen show a mean difference in velocity of $-21{\cdot}6$ km./sec. between the emission and absorption lines. A solution for solar motion, galactic rotation and absolute magnitude gives a mean value of $-1{\cdot}4$ for the absolute magnitude of the N-type stars.

The cause of systematic differences between velocities derived from different elements in a star has been investigated by Adams and McCormack (*Ap. J.*, **81**, 119). In nine stars of different spectral types, all near enough to eliminate effects of interstellar absorption, several lines (of which [*H*], [*K*], [*D*] and a pair of *Al*I lines are the most important) give systematic differences of about -5 km./sec. from the normal stellar lines. The authors suggest the hypothesis of a gradually expanding envelope as the best explanation of these observations. In three stars the *Fe*I lines give larger results than those of ionized *Fe*, and *Ce*II gives larger results still. In such cases radial convection currents affecting lines of different levels differently seems to afford the only adequate explanation.

Some useful tables to assist the reduction of radial velocities to the Sun, for use in conjunction with a computing machine, are given by S. Herrick, jun. (*L.O.B.*, 470).

A lengthy series of observations of α Cygni by G. F. Paddock (*L.O.B.*, 472) confirms the variable radial velocity of this star; but though the variation is definitely oscillatory, neither period nor amplitude is constant. The velocity curve is complex, and possibly composed of several periods, of which the dominant period may be due to a cepheid-type of pulsation.

The suspected short-period variation in the radial velocity of α Lyræ has been investigated by Neubauer (*L.O.B.*, 473), who gives strong evidence

against such variation. He finds a mean radial velocity of $-13{\cdot}9 \pm 0{\cdot}04$ km./sec., with no variation greater than about 0·2 km./sec.

Spectroscopic Parallaxes.—An important catalogue of the spectroscopic absolute magnitudes and parallaxes of 4179 stars has been published by Adams and others (*Ap. J.*, **81**, 187). The methods used in obtaining these parallaxes are the same as those previously adopted at Mount Wilson except for the use of some additional pairs of lines and for the application of minor corrections to the reduction curves necessitated by the large increase in the number of available trigonometrical parallaxes. The stars are mostly of types F to M, and all Boss stars of these types North of declination $-26°$ are included, as well as many fainter stars from selected areas or which are of special interest on account of proper motion. Most of the stars given in previous lists are also included, with complete re-determination of their absolute magnitudes and parallaxes.

F. Becker (*Z. f. Ap.*, **10**, 311 ; *ibid.*, **11**, 148) has employed Lindblad's cyanogen criterion (using trigonometric parallaxes for the reduction curves) in obtaining the absolute magnitudes and parallaxes of 738 G–K stars in Kapteyn's Areas 92 to 206.

A quantitative study of the lines used for determining spectroscopic parallaxes in F-type stars has been made by Hynek (*Ap. J.*, **82**, 338). For each F sub-type a quantitative summary is given of the behaviour of five line ratios used at Mount Wilson, and their sensitivity as luminosity criteria is found to vary with spectral type. The lines 4226 (*Ca*I) and 4045 (*Fe*I) are found to behave abnormally in types F8–G0. Their intensity decreases with increasing luminosity in dwarfs but increases in giants, reaching maximum intensities which are identical for $M = +4{\cdot}5$ and $M = -3{\cdot}5$. The diffuseness of lines, measured through the parameter width/depth indicates various degrees of rotational broadening in F-type stars and confirms the scarcity of rapidly rotating stars of types F0–F5. It is also shown that diffuse-line stars are distributed over a considerably smaller range of spectroscopic absolute magnitude than the sharp-line stars.

Miscellaneous.—The advisability of attempting a new system of classifying stellar spectra has been considered by Russell, Payne-Gaposchkin, and Menzel (*Ap. J.*, **81**, 107). After describing the general problems of classification they discuss Struve's suggestions in detail, and outline the main prerequisites for a definitive classification based on theoretical considerations. They consider that the mere existence of the Draper classification, in which the principal parameters are closely related to fundamental properties of stellar atmospheres and which has already been applied to hundreds of thousands of stars, is conclusive argument for its fundamental conservation. Further classification, especially of the bright stars, is desirable when sufficient observational material is available ; but at the present time it is considered to be premature.

A partial list of c-stars of types B and A is given by Merrill (*Ap. J.*, **81**, 351), who lists 95 c-stars of these classes which have been discovered or confirmed by slit spectrographs at Mount Wilson.

W. Becker (*Z. f. Ap.*, **11**, 98) has discussed the colour excesses of a number of c-stars, based on photo-electric colour indices from Berlin, Washburn and Yerkes. The coefficient of selective absorption varies in different regions of the sky from $0^m.0$ to $+0^m.5$ per kiloparsec for λλ 4260 and 4770. In the case of c B-type stars the colour excess has large positive values in all spectral regions from the blue to infra-red, but later types only show this effect in the blue region. This reddening can be accounted for simply by selective interstellar absorption in the case of B stars, but in later types it must have a stellar origin. The hypothesis is also suggested that the Sun is in a narrow zone of absorbing matter (with a coefficient of selective absorption $= +0^m.4$ per kiloparsec) which stretches from the direction of Taurus to the opposite point of the celestial sphere.

The visual region of the spectra of eight early type stars has been measured by Marshall (*Ap. J.*, **82**, 97), who gives wave-lengths and estimated intensities for 357 lines over the region 4713 to 6678 A. About 56 per cent. of these lines are considered to be satisfactorily identified.

A detailed study of the spectrum of Arcturus has been made by S. G. Hacker (*Contr. Princeton Obs.*, No. 16), who lists about 3900 lines in the region 4100–6700 A. Wave-lengths are given to 0·01 A., corrected for a radial velocity of −6·17 km./sec. (derived from 1099 lines); intensities by visual estimates on an arbitrary scale; and identifications through a detailed study of the multiplets of various elements.

The spectrum of α Lyræ in the ultra-violet has been measured by R. W. Shaw (*Ap. J.*, **82**, 87). Wave-lengths of 118 lines between 3000 and 3480 A. are given, of which 74 have been identified with lines of *Al*I and II, *Cr*II, *Fe*I and II, *Mn*II, *Ti*II, *V*II and *Na*I.

D. L. E.

Variable Stars

1. *General Publications.*—One of the most important publications of the past year in the vast field of Variable Star Astronomy is the first volume of R. Prager's history and bibliography of the variable stars (by arrangement with the A.G. published in *Veröff. Univ. Sternw. Berlin-Babelsberg*). It represents the second edition of Müller and Hartwig's *Geschichte und Literatur*, which was up to date only to 1915. Prager's work contains the complete results obtained in the years 1916–1933. The first volume combines all known photometric and spectroscopic data in monographs for 1406 variables, arranged in the alphabetical order of the constellations Andromeda to Crux. Two other similar volumes will follow, as well as a fourth supplementary volume with the material appearing during course of publication. The work is reviewed by Wyse, *P.A.S.P.*, **47**, 110; Ebell, *A.N. Lit. Beibl.*, 102; and Fr. Becker, *Himmelswelt*, **45**, 77.

The "Atlas Stellarum Variabilium, Series octava," from the *Specola Vaticana*, Rome (J. G. Hagen, S.J., Fr. Becker, M.Esch., S.J., and Fr^a W. Wright, edited by J. Stein, S.J.), is described in detail by P. Guthnick (*V.J.S.*, **70**, 3). There are 61 variables on 41 maps, the position of the

comparison stars, their photovisual magnitudes supplied by the Harvard Observatory, etc. J. Stein discusses this edition in *Pop. Astr.*, **43**, 263.

The useful "Atlas d'étoiles variables," by Z. Kopal and V. Vand, of the Štefanik Observatory, Prague, as well as V. Vands's "Small Atlas," are discussed by R. Prager (*V.J.S.*, **70**, 11).

In the same number of the *V.J.S.* (**70**, 16) Prager pays a well-earned tribute to vol. **31** of the *Memoirs of the British Astronomical Association*, *i.e.* the eleventh report of the section for the observation of variable stars.

A second catalogue of the positions of variables has been published by C. Bac (*Publ. Observatory Lyon*, sér. 1, vol. **1**, No. 11) continuing the similar Lyon publication of the year 1927. In *A.N.*, **255**, 93, E. Zinner gives results for 56 variables or suspected stars which form part of his Bamberg observing programme of 1400 selected stars. Mention must be made of Banachiewicz' ephemerides of eclipsing binaries in *Rocznik*, Cracow, No. 14, which prove very useful. No. 15 of the *Kl. Veröff. Berlin-Babelsberg* forms Prager's well-known *Katalog und Ephemeriden veränderlicher Sterne für* 1936, containing the 6776 variables recognised till the end of 1935.

2. *Observational Material.*—The number of variable star observers and of the objects with which they are dealing is steadily increasing. Here we are able only to mention in detail some of the more comprehensive collections of material.

First of all, Leon Campbell's "Monthly Reports of the American Association of Variable Star Observers," which were regularly published in *Pop. Astr.* For 1935 January, for example, he can quote no less than 4570 observations of 417 variables made by 109 members of the Association (*Pop. Astr.*, **43**, 159). More than 54,000 observations were so collected in 1935. H. Shapley (*Science*, **80**, 542) gives a survey of the variable star work carried out by the Harvard Observatory.

French variable star observers are publishing in *Bull. de l'assoc. française d'observateurs d'étoiles variables*, Lyon, vols. 3–4 (H. Grouiller, M. Bloch, C. Buisson, etc.), their numerous observations of long-period and irregular stars.

In No. 12 of the *Publications de l'Obs. de Lyon* A. Brun deals with the variables in the Orion nebulæ; in No. 13 Ssu-Pin Liau makes a special photometric study of GO and X Cygni.

The Russian publications during the past year have again contributed most valuable material for the study of variable stars of all types. For instance, we find extensive studies in *Veränderliche Sterne*, vol. **4**, etc. (edited by M. A. Borčev and B. W. Kukarkin, Gorki). P. Th. Shajn has discovered numerous new variables on Simeïs plates; E. R. Mustel has studied the irregularities of U Delphini, etc.

Japanese observations, made by the members of "The Astronomical Society of Japan," have been published in *The Astronomical Herald*, vol. **28**.

The variables in Kapteyn's Selected Area 41 were the object of a monograph by A. A. Wachmann (*A.N.*, **255**, 341; *Astr. Abh. Hamburger Sternw. Bergedorf*, vol. **4**, No. 5, p. 93).

Two extensive systematic studies of variable stars appeared in the

Harvard Ann. In No. 4, vol. **90**, H. Shapley and E. M. Hughes treat the newly discovered variables in high galactic latitudes; in No. 5 H. Shapley and H. H. Swope the stars in low latitudes.

Hoffmeister (*A.N.*, **255**, 401, 411) and Morgenroth (*A.N.*, **254**, 370; **255**, 365, 425; **257**, 137) list long series of their new discoveries.

W. J. Luyten (*A.N.*, **256**, 325) supplements his discoveries in the Southern Hemisphere with his eighth list, containing 381 new variables.

Special photo-electric and photometric investigations of three variables of considerable interest were carried out by P. Guthnick (*Sitz. Ber. Akad. d. Wiss. Berlin, Phys.-Math. Kl.*, 1934, *XXX*).

Besides the above-mentioned references the very extensive observational material, secured by numerous observers from all countries, will be found more or less scattered throughout the sources quoted in the other sections of this account.

3. *Statistical Work, etc.*—E. A. Kreiken (*A.N.*, **254**, 97) investigates some irregularities in the distribution of the eclipsing and δ Cephei variables in various regions of the sky. The classification of the variables is dealt with by E. Loreta (*A.N.*, **254**, 94, and *Rev. Soc. Astr. Esp. y Am.*, **24**, 90), who proposes six different types. He studies also relationships between period, maximum brightness, absolute magnitude, etc. (*A.N.*, **254**, 183; *A.N.*, **256**, 299). The statistics of the periods, using Prager's catalogue for 1935, are dealt with by K. Royer (*A.N.*, **256**, 69).

H. Shapley (*Harv. Bull.* 901) draws attention to the "Harvard Milky Way Field 233," and points out that there a large number of variable stars have been found in a region which is also well populated with external galaxies. Therefore the essential transparency of space is assured, and the value of the variable stars in measuring galactic distances is greatly enhanced. The distances of the variables investigated are greater than 40,000 parsec. Shapley concludes: This general region of the sky should eventually be searched for very faint variable stars, since the indicated window in the absorbing cloud will provide a good opportunity for the exploration of the galaxy that lies beyond the galactic centre.

4. *Instrumental.*—Remarkable progress in the application of a new method for studying short-period variables has been made at the Harvard Observatory. S. Gaposchkin describes it in *Harvard Bull.* 898 as an automatic device which makes a number of successive short exposures on one plate, and thus enables the study of periods, light-curves, changes of energy distribution, and other properties of the star to be made. Three different instruments, each with appropriate plate and filter, have been used in order to obtain simultaneously red, yellow and blue magnitudes. The results were very satisfactory; among other stars the cluster type variable B.D. +0° 4900 has been studied, which, with 88 minutes, has the shortest period now known.

C. Payne-Gaposchkin (*Harvard Bull.* 898, 3) applied these automatic multiple exposure cameras for the investigation of the interesting eclipsing binary GO Cygni; and S. Gaposchkin (*Harvard Bull.* 900, 13) for the study of XX and XZ Cassiopeia.

W. A. Calder (*Harvard Circ.* 405) gives an account of the new equipment for photo-electric photometry which has been installed at the Harvard Observatory since 1932, and of the first steps in a programme which is concerned with the evaluation of the constancy of stellar radiation.

5. *Theory.*—Applying S. Chandrasekhar's fundamental investigations of the double-star problem in relation to the equilibrium of distorted polytropes (in *M.N.*, **93**, 462, 1933), the gravitational effect in eclipsing systems has been studied by W. Krat (*Zs. f. Ap.*, **9**, 319). He gives numerical applications of the formulæ in the case of the systems X Trianguli and *u* Herculis.

"The physical elements, age and evolution of eclipsing binaries" is the title of Zdĕnek Kopal's work in *Zs. f. Ap.*, **9**, 239. On the basis of a new empirical form of the mass-luminosity curve he discusses relations between the latter and the surface temperature of the stars, and determines elements for 41 eclipsing systems with a view to cosmogonical problems in connection with the work of Jeans and Milne.

Theories of long-period variables are critically regarded in considerable detail by P. W. Merrill (*Pop. Astr.*, **43**, 214). J. Parenago (*Russian Astron. Journ.*, **5**, 455) deals with systematic errors in the eye-observations of red variable stars, giving a formula to take them into account, which makes use of the star-temperatures. Of general interest is T. E. Sterne's article "Errors in the Periods of Variable Stars" (*Pop. Astr.*, **42**, 558). See also *Harvard Circ.* 386, 387.

Oxford University Observatory has issued as No. 3 of its publications I. A. Getting's characteristic curves of some variable stars, being applications of E. A. Milne's new method of analysing stellar variability. Also, A. E. H. Bleksley (*Zs. f. Ap.*, **11**, 59) discusses the bearing of his results on Milne's diagram, when he investigates, using visual and photographic light-curves, the relation between photospheric radius and temperature of a number of Cepheid variables, particularly of RS Bootis.

V. Ambarzumian (*Observatory*, **58**, 152) derives, as consequence of Oort and Lindblad's theory of the rotation of the galaxy, the mean life-time of the cluster type variables.

The effect of the second-order terms in the pulsation theory of Cepheid variation has been studied by H. A. Kluyver (*B.A.N.*, **7**, 265). Some aspects of the pulsation theory are discussed by G. Thiercy (*Publ. Geneva*, sér. A, No. 30, p. 271). E. A. Fath (*Lick Obs. Bull.*, **17**, 115) deals with the pulsation in stellar atmospheres, discussing observations of α Lyræ, β Canis Majoris, α Cygni. Small fluctuations in brightness appear to be real, and to be correlated with similar small fluctuations in radial velocity. See also *P.A.S.P.*, **47**, 232. The internal constitution of the eclipsing variables is dealt with by H. Klauder (*A.N.*, **255**, 1 ; *Mitt. Sternw. Jena*, No. 5).

6. *Eclipsing Variables.*—Scarcely any other eclipsing binary has attracted so much attention as ζ Aurigæ, on the occasion of its eclipse, 1934–1935 (see *M.N.*, **95**, 406). Since it can probably be assumed that no further papers will appear on this last eclipse, and on account of the general importance of the results obtained, it seems advisable to give here in alphabetical

order a fairly complete list of the ζ Aurigæ literature. (Papers not contained here will be found in *M.N.*, **95**, 24, etc.) Becker (*Himmelswelt*, **45**, 243), Beer (*M.N.*, **95**, 24), Christie and Wilson (*Ap. J.*, **81**, 426 ; *A.N.*, **257**, 183), Fedtke (*Sterne*, **15**, 35 ; *Himmelswelt*, **45**, 169), Florja (*A.N.*, **256**, 430), Gaposchkin (*Harvard Bull.* 900, 18), Guthnick-Schneller-Hachenberg (*Abh. Pr. Akad. d. Wiss, Berlin, Phys. Math. Kl.*, 1935, No. 1), Guthnick-Schneller (*A.N.*, **256**, 389 ; *A.N.*, **257**, 184), Guthnick (*Research and Progress*, **2**, 19), Hassenstein (*A.N.*, **256**, 265), Hopmann-Schaub (*A.N.*, **257**, 231), Huffer (*Ap. J.*, **81**, 292), Landwehr (*Himmelswelt*, **45**, 34 ; **45**, 251), McCrea (*Observatory*, **58**, 276), Oosterhoff (*Ap. J.*, **81**, 461), Plassmann (*Himmelswelt*, **45**, 204), Russell (*Scientific American*, **152**, 70), Schneller (*Sterne*, **14**, 276, and **15**, 185), Smart and Green (*M.N.*, **95**, 31), Sommer (*Sterne*, **15**, 62), Swope (*Harvard Circ.* 399), Tremblot (*C.R.*, **198**, 1977), Vyssotsky-Reno (*A.J.*, **44**, 79), Wyse (*P.A.S.P.*, **46**, 28), Zonn (*Acta Astr.*, sér. C, vol. **2**, p. 93 ; *Bull. Obs. Wilno*, No. 16).

New elements and physical properties of the ζ Aurigæ-system have been derived in considerable detail, although there are still some photometric difficulties in the interpretation of the partial phase. W. H. Christie and O. C. Wilson have devised a spectrophotometric method for eliminating the effect of the K star in the composite spectrum of the system. They succeeded in measuring the total amount of light absorbed from the continuous spectrum of the B star by the various atoms in the atmosphere of the K component. Changes of total absorption were investigated for about a hundred lines. Thus the relative number of atoms, derived from the total absorption of the various elements at different heights above the K-star photosphere, shows six different classes : neutral metals, *Mg*, *Si*II (two groups), *H*, *Ca*II. No adequate hypothesis accounts for all of the observed distributions.

A "Programme of Investigations of Eclipsing Variables" is developed by D. T. Martinoff (*Bull. Engelhardt Obs., Univ. of Kasan*, No. 2), which lists 291 variables of special interest to be followed in future. R. Prager discusses this paper in *V.J.S.*, **70**, 9, where he also reviews R. S. Dugan's important finding list for observers of eclipsing variables in *Princeton Contr.* No. 15 (see *M.N.*, **95**, 405).

Very useful tables for the observers of eclipsing variables have been calculated by S. Gaposchkin (*A.N.*, **254**, 397), enabling the observer to decide rapidly if his observations and his light-curve lead to a reasonable result ; *i.e.* to decide, without applying rigorous methods, whether the observations really fulfil the requirements of an eclipsing variable, whether the observations are sufficiently good, or whether the star itself is in some way peculiar.

Other tables of interest for the computer of orbits of eclipsing binaries have been supplied by W. P. Zessewitsch, extending Fetlaar's work (*Tadjik Obs. Circ.*, No. 7).

Numerous orbital elements of eclipsing binaries have been computed or redetermined.

Observations of eclipsing variables in different wave-length regions were made by J. Hellerich (*A.N.*, **256**, 405). Photometric-colorimetric investiga-

tions of 12 eclipsing binaries were carried out by P. Skoberla in Breslau (*Zs. f. Ap.*, **11**, 1), who presents a thorough discussion of the phenomena of Nordmann-Tikhoff, Purkinje and Gallissot.

H. Shapley and W. A. Calder (*Harvard Circ.* 398) undertook a photometric investigation of the much discussed eclipsing system *u* Herculis, based on observations made with the new Wyeth reflector at the Oak Ridge Station of the Harvard Observatory. It revealed many points of interest, especially the conclusion that the apsides regress in a period of about 20–25 years.

Gaposchkin (*Harvard Bull.* 898) compares spectra of eclipsing variables observed by Miss Cannon (*Harvard Bull.* 897) with the spectral types to be predicted on the basis of relative surface brightness and radius.

The variability in the *Hα* emission of ε Aurigæ is the subject of a note by D. B. McLaughlin (*Ap. J.*, **82**, 95), who notices on a plate taken during the total phase of the 1929 eclipse a distinct *Hα* absorption, which had disappeared in 1935, evidently filled up by an emission.

W. A. Calder (*Harvard Bull.* 899, 13) tested with his electrostatic photometer the suspected short-period variability of Procyon without finding support for the hypothesis of an invisible companion. Algol observations are discussed by H. Grouiller (*l'Astronomie*, **49**, 369), etc. Work on β Lyræ is done by H. Grouiller and M. Bloch (*Lyon Publ.*, sér. 1, No. 14). An accurate photo-electric light-curve based on observations of W. M. Smart and H. E. Green appeared in *M.N.*, **95**, 644. A. C. Maury (*Harvard Bull.* 899, 25) publishes a preliminary note on the evidence of a long-period variation of five years in the spectral changes of the β Lyræ-system.

7. *Cepheid Variables.*—The "Catalogue and Ephemerides of Short-period Cepheids for the years 1934–1935" is published by W. Zessewitsch in *Leningrad Univ. Astr. Obs. Bull.*, No. 4. For 1935–1936 the same author publishes his catalogue in the *Publ. of the Tadjik Astron. Obs. Stalinabad*, and refers to all RR Lyræ stars down to $12^{m}.5$ at maximum not contained in globular clusters. Extensive investigations of numerous stars of this type are due to A. V. Soloviev, who, using many thousands of visual observations, derives light-curves, etc. (*Ann. Tadjik Astr. Obs.*, vol. **1**, pt. 1; *Veränderliche Sterne*, **4**, 377).

A. A. Nijland (*B.A.N.*, **7**, 248) gives maxima observations for 12 Cepheids. Epochs of maximum for 38 faint Cepheids are derived by P. Th. Oosterhoff (*Harvard Bull.* 900, 9).

Long series of photographic and photovisual observations of Cepheids are investigated by H. Kox (*A.N.*, **256**, 21; *Astr. Abh. Hamburger Sternw. Bergedorf*, vol. 4, p. 73), who discusses the resulting deviations of the Cepheid radiation from black body radiation. Comprehensive photographic results for 13 δ Cephei stars are summarized by J. Hellerich (*A.N.*, **256**, 221).

The variability of Polaris was photo-electrically investigated by E. J. Meyer (*A.N.*, **256**, 421). A photo-electric light-curve of δ Cephei is discussed in detail by W. M. Smart (*M.N.*, **95**, 644).

Research work on the isolated cluster variables near M53 has been done

by E. Grosse (*Mitt. Sternw. Hamburg-Bergedorf*, vol. 7, No. 38, p. 91); and by J. L. Greenstein (*A.N.*, **257**, 301) on the periods and the light-curves of the variables in M3. See also Greenstein, *Harvard Bull.* 901.

The zero-point of the period-luminosity relation is discussed by J. J. Nassau (*A.J.*, **44**, 33) using 34 Cepheids.

Interesting work on the radial velocity variation of Cepheid variables was done by R. F. Sanford, mostly based on Mount Wilson spectrograms, and deals with FF Aquilæ (*Ap. J.*, **81**, 132), Y Ophiuchi (*Ap. J.*, **81**, 140), RR Lyræ (*Ap. J.*, **81**, 149).

8. *Long-period Variables.*—The present state of the problems offered by the long-period variables is discussed fully by A. D. Thackeray (*Observatory*, **58**, 285).

G. Shajn (*Zs. f. Ap.*, **10**, 73) publishes an extensive study on the hydrogen emissions in the spectra of long-period variables of the types *Me*, *Se*, *Ne*, *Re*, pointing out the influence of some molecular bands, *e.g. TiO*, *ZrO*, C_2, *CN*, *CH*. The existence of the bright lines in the spectra (with special regard as to the work of Merrill and Joy on Mira Ceti) is traced back by K. Wurm (*Zs. f. Ap.*, **10**, 133) to exothermal chemical reactions, especially to recombinations of atoms to diatomic molecules in the outer atmospheres. The intensity variation of *TiO*, *AlO*, *AlH*, in Mira Ceti during the period of its light variation is discussed by Yoshio Fujita in his study on the dissociation of diatomic molecules (*Japanese Journ. of Astron. and Geophys.*, vol. **13**, No. 1). The periods of the long-period variables are analysed by J. v. d. Bilt (*Hemel en Dampkring*, **33**, 99).

P. W. Merrill undertakes a comprehensive study of the spectrum of R Aquarii as it appeared in 1919–1934. It proved convenient to discuss the Mount Wilson observations as though R Aquarii consisted of three light sources, all variable: a red long-period variable, type M7e; a gaseous nebula, P; and a blue "companion," Ofp or Bep. Until 1925 the nebular lines λλ 4363, 4959, 5007 were conspicuous, thereafter they became very weak. Data on displacements of different lines reveal discordances. The spectrum of the hypothetical companion has been visible since 1922, first resembling the nucleus of a planetary nebulæ of type Ofp, later changing to Bep. Those spectroscopic data, obtained in great detail, enabled Merrill to make a partial analysis of the light-curve into two curves—one for the Me star, the other for the companion. Merrill points out similarities to three irregular variables, *e.g.* Z Andromedæ, and concludes that "factors of general astrophysical interest may lie back of the observed phenomena."

9. *Irregular Variables, etc.*—The light-curve of SS Cygni, belonging to the U Geminorum type, is statistically investigated by L. Campbell and T. E. Sterne (*Harvard Bull.* 897), taking into account the results of 37 years' observation (see also *Harvard Ann.* 90, Nos. 3, 6). H. Grouiller (*l'Astronomie*, **49**, 238) again draws attention to the importance of future observations of this star. The maxima of SS Cygni and its group are statistically treated by G. R. Miczaika (*Zs. f. Ap.*, **10**, 224). Additional observations are supplied, *e.g.* by J. Rosenhagen (*A.N.*, **257**, 244).

W. Theile (*Himmelswelt*, **45**, 78) draws attention to the anomalies of

UU Herculis, representing a peculiar type of variability (see, *e.g.*, M. Beyer, *Erg. Hefte d. A.N.*, **8**, No. 3, C. 44).

The R Coronæ type is the subject of short notes by E. Loreta (*A.N.*, **254**, 151) and by F. Buser (*A.N.*, **257**, 184), and of a very thorough study by L. Berman (*Ap. J.*, **81**, 369). Berman discusses about 650 lines measured on Lick spectrograms, and derives the chemical composition of the stellar atmosphere, which was found to be 69 per cent. carbon, 27 per cent. hydrogen, less than 0·3 per cent. nitrogen, and 4 per cent. metals, chiefly magnesium and iron. The resulting optical depth of the photospheric level for this "hot carbon star" is discussed, and the physical parameters that define the state of its atmosphere are very completely presented.

10. *Novæ.*—The outstanding event of the past year, at least in the working field of variable star observers, was doubtless the observation of Nova Herculis 1934. A great number of papers have already been published, and we may expect a still greater number in the future. The results hitherto obtained are summarized completely in a separate Council note in this number of the *M.N.* In this section we are only concerned briefly with the publications of 1935 regarding previous new stars.

Harvard Circ. 406, which represents A. B. Sayer's fundamental study on the early spectrum of Nova Aquilæ 1918, is summarized as follows: Quantitative relations between radial velocity and intensity in the bright hydrogen bands have been determined for a period of about a month following discovery. Important structural variations are shown, a new type of profile has been measured, and possible need for revision of the theory of formation of absorption lines is indicated. The hypothesis is put forward that the ejection of nebulous matter was asymmetrical. Maximal and minimal numbers of atoms in the second quantum state of hydrogen have been computed from absorption-line data. The radiation from the nebular shell, integrated with respect to radial velocity, is found to be essentially continuous from λ 3790 to the limit of the Balmer series. The hydrogen absorptions are shown to be formed in the outer portions of the nebular shell: the velocity dispersion there is small. The lack of a serious break in the intensity distribution at the limit of the Balmer series indicates that the material of the nova shell is of higher density than that of the planetary nebulæ, in which such a discontinuity is observed.

An interesting contribution to the theory of novæ was made by W. H. McCrea (*M.N.*, **95**, 509), who considers theoretically the phenomenon of gas-streaming, and concludes that the densities required to ensure that the gases in the expanding envelopes of Wolf-Rayet stars and novæ should move with an almost common velocity are of a quite plausible order of magnitude.

The problem of the classification of different types of novæ is investigated by K. Lundmark (*Medd. Lund.*, s. 2, No. 74).

The present state of our knowledge regarding new stars was discussed in detail at the 1935 British Association Meeting at Norwich by H. Spencer Jones, J. P. M. Prentice, F. J. M. Stratton, W. H. McCrea, E. G. Williams, A. B. Wyse, R. H. Stoy (see McCrea, *Nature*, **136**, 501).

S. Gaposchkin (*Harvard Bull.* 899, 5) makes a calculation of the initial

radii of seven novæ with good observational data. The assumption is that the nova phenomenon is due to an expansion ; his formulæ connect the initial radius, the time of increasing light, the average velocity throughout this time-interval, the total relative increase of luminosity and the relative surface brightness. In *Harvard Bull.* 901 he uses the radii to derive absolute magnitudes, and finds a fairly good agreement with the trigonometrical values.

H. Shapley and E. M. Hughes describe in *Harvard Bull.* 898 their discovery of Nova Tucanæ 1927, one of the very rare new stars in the small magellanic cloud.

A possible nova, found on Johannesburg plates, is reported by W. E. Kruytbosch (*B.A.N.*, **7**, 262). The star seemed to have exhibited the unusual behaviour of rising over two magnitudes in about half an hour. J. G. Ferwerda finds a nova, maximum at least $12^{m}\cdot9$, on 1931 plates in Sagittarius (*B.A.N.*, **7**, 273).

A short note by E. Loreta (*A.N.*, **257**,78) deals with the light-curves of novæ.

B. Vorontsov-Velyaminov (*Zs. f. Ap.*, **10**, 353) continues his discussion of the "bright-band effect" and its influence on the photographic magnitudes, and notes that this influence can amount to a difference of some magnitudes.

The determination of the most probable position of Nova Ophiuchi 1604, based on Kepler's and Fabricius' observations, is attempted by O. Schlier (*A.N.*, **254**, 181).

W. H. Steavenson (*M.N.*, **95**, 639) has published an extensive continuation of his magnitude observations of the following former novæ : N. Aquilæ 1918, N. Aquilæ 1925, N. Aurigæ 1891, N. Coronæ 1866, N. Cygni 1876, N. Cygni 1920, N. Lacertæ 1910, N. Lyræ 1919, N. Ophiuchi 1848, N. Persei 1901.

In conclusion mention must be made of the work done on the related P Cygni problem : C. S. Beals published an interesting paper on the behaviour of carbon, nitrogen and silicon in the spectrum of this star (*M.N.*, **95**, 580), while the whole spectrum of P Cygni was made the subject of a detailed analysis by Otto Struve (*Ap. J.*, **81**, 66), with a view to testing the theory of an expanding nebular shell. Struve concludes that the nucleus of P Cygni has an effective temperature of 20,000°, but selective interstellar absorption reduces the colour temperature to about 6000°. There is no line spectrum belonging to a stationary reversing layer ; absorptions and emissions originate in an expanding nebular shell. The velocity of this shell is about 200 km./sec. in the region of formation of the *H*-lines, and about 50 km./sec. in the case of *Si*IV and *N*III. The problem of the depths at which a given absorption line originates, and especially the mechanism of line excitation, are further points fully discussed in Struve's paper. A. B.

Double Stars

New Pairs.—The most interesting discovery during the year 1935 is that of the duplicity of Nova Herculis by Kuiper (*P.A.S.P.*, **47**, 228). This recalls Finsen's discovery of the duplicity—later on triplicity—of Nova Pictoris in 1928.

Kuiper also publishes : 6 new bright close binaries (*P.A.S.P.*, **46**, 359), a triple star of large parallax (**46**, 361), 3 new close double stars of large parallax (**47**, 98), 7 new double stars (**47**, 230), and 2 close binaries of large proper motion (**47**, 279).

Milburn lists his pairs 913–969 (*M.N.*, **95**, 298).

Measures.—Komendantoff gives measures of 408 pairs, 15-inch (*Poulkovo Publ.*, 2nd series, vol. **47**).

U.O.C. 94 contains measures of 354 pairs by van den Bos, 26½-inch mostly.

Baize publishes measures of 211 pairs, 12-inch (*J.d.O.*, **18**, 65, 89 and 148).

Aitken gives measures of 84 pairs, 36-inch (*L.O.B.*, **17**, 91).

Phillips 73 pairs, 8-inch (*M.N.*, **95**, 186).

Doberck 62 pairs, 6-inch (*A.N.*, **254**, 41).

Barbier 61 pairs, 10-inch (*J.d.O.*, **17**, 146).

Milburn 24 pairs, 24-inch reflector (*M.N.*, **95**, 298).

Kuiper gives measures of B.D. – 8° 4352, which has a remarkably short period, less than two years (*P.A.S.P.*, **46**, 360).

Measures of Nova Herculis are given by Simonow (*A.N.*, **256**, 300).

U.O.C. 93 contains the second series of interferometer measures by van den Bos and Finsen.

Kazansky and Bugoslavsky give photographic measures of 40 pairs, 15-inch refractor (*A.J. Sov. Un.*, **11**, 4).

Barton (*A.N.*, **256**, 357), Bemporad (*A.N.*, **254**, 37) and Bhaskaran (*J.d.O.*, **18**, 52) publish double-star results from the astrographic zones.

Orbits :—

ADS	Computer	*P*	*a*	*e*	Reference
		y	″		
148	Russell	63·89	0·217	0·750	*P.A.S.P.*, **47**, 222.
671	Simon	431·30	11·273	0·458	*Königsberg Veröff.* 5.
2616	Luyten I	576	0·691	0·71	*Minnesota Publ.* **2**, No. 1.
	,, II	600	0·719	0·71	,, ,, ,,
3064	Voronov	6·79	0·164	0·20	*Tashkent Bull.* 4.
3082	Hynek	170·22	0·52	0·41	*A.J.*, **44**, 151.
	Aller	120·0	0·51	0·119	*A.N.*, **256**, 245.
3588	van den Bos	56·0	0·555	0·80	*U.O.C.* 94.
6993 AB	Slonim	15·15	0·29	0·73	*Tashkent Bull.* 5.
AB, C	,,	2044	9·081	0·63	,, ,,
7555	Martin	78·77	0·368	0·703	*Padova Publ.* 38.
9343	Arrighi	212	1·92	0·592	*A.N.*, **256**, 99.
9578	Komendantoff	207·88	1·207	0·648	*Poulkovo Circ.* 12.
9769	Wilson	140·0	0·397	0·850	*A.J.*, **44**, 68.
11046	Voronov	87·210	4·505	0·472	*Tashkent Bull.* 4.
11186	Wilson	200	0·533	0·92	*A.J.*, **44**, 71.
14773	Luyten	5·70	0·26	0·42	*Minnesota Publ.* **2**, No. 1.
14787	Luyten, Ebbighausen	49·8	0·94	0·27	*A.J.*, **44**, 119.
17175	Luyten, Sheffield	26·46	0·82	0·406	*Minnesota Publ.* **2**, No. 1.
δ 31	Voronov	4·561	0·179	0·236	*Tashkent Bull.* 4.
p Eri	Luyten	251	8·306	0·80	*Minnesota Publ.* **2**, No. 1.
Jc 8	Finsen	39·95	0·515	0·84	*U.O.C.* 94.
I 365	van den Bos	34·80	0·498	0·80	,, 94.
I 120	Finsen	72	0·447	0·72	,, 94.

Miscellaneous.—Dynamical parallaxes for 531 pairs south of $-19°$ are given by Finsen (*U.O.C.* 93). Pitman publishes a paper on the determination of mass ratio in visual binaries (*A.J.*, **44**, 65). Pitman and Kovalenko give the parallax and mass ratio of β 101 (*A.J.*, **44**, 67), van de Kamp the mass ratio of ζ Her (*A.J.*, **44**, 83).

Barton has a note on ADS 457 (*A.J.*, **44**, 39); Zagar on 48 Cas (*Atti Acc. Padova* 51).

Martin publishes papers on orbit methods (*Padova Publ.* 24, 25, 29) and on the effect of change of mass on orbit elements (*Carloforte Publ.* 25–30). Zagar has a paper on the determination of the orbit of a 61 Cyg type binary and on the orbit of a third, invisible component (*Padova Publ.* 42 and 45).

Boneff studies the probability of the existence of non-elliptic binaries (*A.N.*, **256**, 195).

Mrs. Makemson has a study of Sulaiman's theory and the period-eccentricity relation (*A.J.*, **44**, 146). Barbier points out the weakness of the observational evidence for this correlation (*C.R.*, **199**, 930) and studies the eccentricities of long-period binaries (*C.R.*, **198**, 151; and *Bull. Astr.*, **8**, 437). Kuiper reviews the problems of double-star astronomy (*P.A.S.P.*, **47**, 15 and 121). Aitken has published the second edition of *The Binary Stars.*

W. H. v. d. B.

Meridian Astronomy

There have been few council notes in recent years dealing with Meridian Astronomy, the last being *Errors in Right Ascension of Fundamental Star Catalogues* (1915), *Meridian Astronomy* (1924) and *Proper Motions* (1930). Nevertheless a great deal of work has been done, especially at the leading national observatories, as can be seen from the reports of Commission 8 of the International Astronomical Union. It is not possible here to deal with all the publications, but reference may be made to some of the results of greatest importance.

It has long been recognised that it is essential to have an accurate system of fundamental stars. Directly or indirectly the positions of stars, whether determined photographically or visually with meridian instruments, depend on the adopted positions of the fundamental stars, and any systematic errors either in the positions or motions of the fundamental stars will be reproduced in the deduced positions and motions of other stars.

Observations in the present century have generally been reduced by means of one or other of the fundamental catalogues: Auwers, Newcomb, Boss and Eichelberger. With fundamental observations systematic corrections to the basic system have often been determined and applied. The most recent revision of the fundamental systems, based on a comparison of all the fundamental observational catalogues available, is that which has been carried out at the Rechen-Institut and published in a series of papers in the *Astronomische Nachrichten.* The revision has taken the form of the determination of corrections to the *New Fundamental Catalogue* (N.F.K.), which itself was a revision of the original fundamental system of Auwers.

The corrections have been determined in the following forms : (1) equinox correction, (2) magnitude correction in right ascension, (3) periodic corrections in right ascension, (4) corrections in right ascension varying with the declination, (5) corrections to the declinations varying with the declination and also the right ascension. These corrections have to be considered as varying with the time, *i.e.* as affecting both the positions and the proper motions. In determining the corrections the declinations have presented greatest difficulty on account of uncertainty in instrumental flexure, which involves the determination of refraction. The new catalogue known as F.K.3 has been provisionally published in the *Berliner Jahrbuch* for 1936, where the corrections required to reduce N.F.K. to F.K.3 are given for 1925·0, 1934·5, 1935·5 and 1936·5, as well as the positions and motions for 1950·0. F.K.3 will be used for the first time in the *Berliner Jahrbuch* for 1940, but in the intermediate years the reduction from N.F.K. to F.K.3 will be given. A complete publication with a detailed introduction is in preparation. It will give a comparison with other fundamental catalogues for the epochs 1925 and 1950. It was agreed at the meeting of the International Astronomical Union in Paris that F.K.3 should be adopted as the fundamental catalogue to be used in the calculation of the apparent places of stars in all the national ephemerides. This will end the complications which have arisen in star catalogues and time determinations through different almanacs using different places for the fundamental stars.

Equinox Correction.—Formerly the determination of this correction depended entirely on the comparison of right ascensions of the Sun and stars derived from observations made near the time when the Sun crossed the equator. The difficulty in its determination arises from the unsuitability of the Sun for accurate observation and the fact that errors in the observed declination of the Sun are multiplied about $2\frac{1}{2}$ times in calculating the right ascension. Experience has shown that there are systematic differences connected with the observer and the method of observation—eye and ear, fixed wires and hand tapper, self-registering micrometer with or without clockwork. Newcomb found that the inner planets were suitable substitutes for the Sun. In spite of the difficulties different series of observations have shown quite close agreement (see Morgan, *A.J.*, 969, and Kahrstedt, *A.N.*, **244**, 33). The conclusion is that Newcomb's equinox, with which those of Auwers and Boss substantially agree, required a correction of $-0^s{\cdot}05$ about 1910. There has been some disagreement as to how far this is attributable to an error in the adopted motion of the equinox and how far to changes in the methods of observing. It is now generally agreed that the motion of the equinox adopted by Newcomb should not be altered. Kahrstedt gives the following corrections to the fundamental systems to reduce to F.K.3 :—

Newcomb	$-0^s{\cdot}050$.
Boss (P.G.C.)	$-0^s{\cdot}045 - 0^s{\cdot}002(T - 1900)$.
N.F.K.	$-0^s{\cdot}048 - 0^s{\cdot}007(T - 1900)$.

Eichelberger in his catalogue adopted corrections to the position and motion

of Newcomb's equinox. To reduce Eichelberger's catalogue to F.K.3 the following corrections, which vanish for 1920, are required :—

$$-0^s.011 + 0^s.055(T - 1900).$$

The number of stars contained in the fundamental catalogues has been about a thousand. Additional stars have been selected for F.K.3 to bring the number up to about 1500, while a few stars used in the past and now considered unsuitable have been dropped. This number appears to be adequate for a fundamental visual system of bright stars, but for many purposes a larger system is desirable. Boss's *Preliminary General Catalogue* contains 6188 of the brighter well-observed stars. This should be replaced in a year or two by the *Albany General Catalogue*, which will contain over 32,000 stars. It is intended to print the catalogue in five volumes. The four to appear first will each cover six hours of R.A., while the fifth will contain details of the construction of the catalogue. A selection of stars which have received much attention by meridian observers are the Backlund-Hough stars—the list was published in the *Conn. des Temps* for 1914—which gives with fundamentals a nearly uniform distribution of 3064 stars over the sphere. About two-thirds of these stars are contained in Boss's P.G.C., and most if not all should be in the *Albany General Catalogue.* All these lists contain stars which have been generally well observed in the past on account of their brightness, so that proper motions can now be computed for them. Since photography was introduced for the determination of star positions it has been necessary to observe many thousand stars with meridian circles to supply the necessary basis for the reduction of plates. With plates 2 degrees square bright stars are not sufficiently numerous, and in any case their images are unsuitable for measurement. This led to the formation of a list of Intermediary Stars to be observed as secondary fundamentals and link up the primary fundamentals with the reference stars for photographic plates (*Bulletin du Comité International Permanent*, Tome vii). The distribution of these stars is approximately uniform at the rate of one star to each 4 square degrees. The list of Intermediary Stars, as originally drawn up by Professor Küstner for the northern hemisphere, and by Mr. Hough and M. Lagrula for the southern, contains a large number of faint stars. At that time the magnitude equation was attracting attention, and these stars were suitable for its determination. Out of 6163 stars in the northern hemisphere there are 3446 from magnitude 8·0 to 9·0, and 1029 from 9·1 to 9·5 on the B.D. scale. Although various series of observations of these stars have been published, they have on the whole not been very well observed. It is possible that they may not play an important part in meridian work in the future, as the general use of the self-registering micrometer has made the observation of faint stars more difficult than it was, and the development of the photographic method to plates covering a large area ($5° \times 5°$ or more) should remove the necessity for the observation of so many stars with meridian instruments as was formerly necessary for plates $2° \times 2°$.

An outstanding development in the determination of accurate star

places has resulted from the researches of Schlesinger. Starting with plates covering 25 square degrees he has proceeded to plates covering 140 square degrees ($10° \times 14°$). From the measurement of these plates he has determined the positions of the A.G. stars in the zones $-2°$ to $+2°$, $+50°$ to $+55°$, $+55°$ to $+60°$ and $+20°$ to $+30°$. The *Astronomische Gesellschaft*, with the co-operation of the German observatories and Pulkovo, is reobserving all the A.G. zones north of $-5°$ declination with plates $5° \times 5°$. All the plates have been secured and the measurement and reduction to the system of F.K.3 is proceeding rapidly. To reduce the photographic measures some 13,700 reference stars have been observed six times, each with various meridian circles. This gives an average of about 16 stars per plate. A.G. stars which cannot be measured on the plates—from faintness, duplicity, etc.—are being observed with the meridian instruments. When this work is completed it should be possible to get fairly accurate proper motions for all the A.G. stars in the northern sky. Yale Observatory has undertaken the photographic observation of stars from the equator to $-30°$ declination, and the Cape Observatory farther south.

The determination of the proper motions of stars will be greatly facilitated in the future by the *Geschichte des Fixsternhimmels* (G.F.H.). The idea for this great undertaking originated with Auwers more than fifty years ago, but no attempt was made to carry it out till Ristenpart took it up in 1898. A commission was then formed by the Kgl. Preuss. Akademie der Wissenschaften to carry out the reduction of all meridian observations to the epoch 1875·0. The direction of the actual work was placed under Ristenpart, while Auwers was head of the commission. In the collection of the material a great number of errors in the observational catalogues were discovered, and Ristenpart is perhaps best known through his *Fehlerverzeichnis zu den Stern Katalogen des* 18 *und* 19 *Jahrhunderts*. In this publication reference is made to 422 catalogues; the actual number used in the construction of the G.F.H. was 442. The undertaking suffered setbacks through the departure of Ristenpart for Santiago in 1908, followed by his death and later by the death of Auwers in 1915. In spite of the deaths of subsequent heads of the commission and difficulties of the war and post-war periods the preparation of the G.F.H. was carried on. Under the direction of Professor H. Paetsch, 23 volumes have been published since 1921. Each volume contains the positions of stars for one hour of R.A. for the northern sky, so that the compilation for all northern stars is on the eve of completion. There are in all about 550,000 places for some 170,000 stars derived from three hundred separate catalogues. These volumes will prove of the greatest value to workers on the positions and proper motions of the northern stars, and it is hoped that the publication of the corresponding work for the southern stars will soon be proceeded with.

Use of Minor Planets for Determination of Systematic Errors in Star Places.—Reference has already been made to the use of the planets Mercury and Venus for the determination of the equinox and to the difficulties in the use of the Sun. For some time also it has been recognised that the Sun and planets could be used to fix the position of the equator. As these

bodies, apart from calculable quantities, move in great circles any systematic departure of the observed from the computed places, to the north or the south, could be attributed to a systematic error in the determination of the equator point of the meridian circles. This method has been used with success at various observatories, but the inner planets are not ideal for observation, as they have marked phases and have always to be observed in full daylight. The minor planet Vesta was then suggested. This planet was considered the most suitable on account of its star-like appearance, and the possibility of observing it at night along with the stars, together with the fact that a general theory of its motion was available although nowhere near the accuracy required. For the computation of accurate ephemerides it appeared that numerical integration would be necessary, and in such a case Vesta would offer no advantages over other minor planets. Dneprovsky has therefore considered the use of the four brightest of the minor planets, and while pointing out the difficulties of observation with meridian circles, of getting adequate material in a reasonable time and of making the necessary calculations, he concluded that the work must be undertaken to solve the problem of the equator point. Further possibilities of the method were examined by Numerov, who suggested the use of ten minor planets to be observed both visually and photographically for determining the systematic errors of the assumed star places in the form

$$\Delta\alpha = a + b \sin\alpha + c \cos\alpha + \ldots$$
$$\Delta\delta = a' + b' \sin\alpha + c' \cos\alpha + \ldots$$

The scheme has been critically examined at Yale Observatory, where an actual plan of campaign has been drawn up involving the observation of fourteen minor planets, photographically, over the ten years 1936–46 at two stations. The minor planets have been chosen as bright as possible, consistent with a fairly uniform distribution of the positions at opposition, in R.A. and Dec. throughout the zone from $-30°$ to $+30°$. The plan would involve the taking of about 2000 photographs at each station, for the determination of 164 unknowns (including, for both $\Delta\alpha$ and $\Delta\delta$, first and second harmonics with regard to α in each of six zones of declination). "The observational programme is being actively considered. Observing will probably begin within a year. Constructive criticism will be welcomed" (Brouwer). The scheme is one of first-rate importance. The labour will be immense: securing and measuring the photographs, tying on the reference stars to the fundamental system, computing the planetary orbits with the necessary accuracy, solving the large number of equations for a large number of unknowns. Only a more detailed examination of the equations of condition will show how far it will be possible to separate the numerous unknowns entering into them. If the planets were infinitely distant it would be impossible to separate the eccentricity and position of perihelion from the chief periodic corrections to the system of right ascensions. Also inclinations could not be separated from corrections to the declination varying with the declination. But with comparatively near planets with large eccentricities observed over a long arc the unknowns are at least

theoretically separable. (See Dneprovsky, *Poulkovo Bull.* 112; Numerov, *Bull. of Leningrad Astr. Inst.*, 32; Brouwer, *A.J.*, 1022.)

In the meantime an actual solution of the problem has been made by N. Voronov in *A.N.*, 6092–3, by means of the existing observations of Vesta. The general theory of the motion of this planet as developed by Leveau has been revised and extended to include perturbations of the second order of the mass of Mars and the third order of masses of Jupiter and Saturn. The theory is believed to be exact to 0″·01 or 0″·02 and has been compared with observations from 1807 to 1932. Corrections are found to the orbital elements of the Earth and Vesta, to the masses of Mars, Jupiter and Saturn, and to Boss's system of Right Ascensions and Declinations. These latter corrections take the form :

$$\Delta\alpha = -0^s\cdot046 + 0^s\cdot000\,(T-1900) - 0^s\cdot001 \sin\alpha + 0^s\cdot002 \cos\alpha,$$
$$\Delta\delta = +0''\cdot315 + 0''\cdot166\,(T-1900) - 0''\cdot019 \sin\alpha + 0''\cdot016 \cos\alpha.$$

The residuals of Leveau's theory and the revised theory are given for each opposition. The final residuals are small and after 1826 rarely exceed 0″·2 and are generally under 0″·1.

It would be too much to expect the corrections found by Voronov to be final, but they are similar to corrections found directly from fundamental meridian observations. The equinox correction is very close to that generally accepted, but the periodic terms are much smaller than those found at several observatories. The need for a considerable positive correction to Boss's declinations has been felt for some time.

Future of Meridian Astronomy.—In view of the success which has attended the use of wide-angle lenses in determining star places many astronomers are of the opinion that as much as possible of meridian astronomy should be taken over by photography. There is no doubt that for mass production photography is preferable on account of economy both of money and observing time. Also when sufficiently accurate positions of suitable reference stars are available the method can be recommended from the point of view of accuracy. There is no doubt that the accuracy of meridian observations fall off as stars near the limit of visibility are observed, and, moreover, such stars can only be observed on the most transparent nights. It appears, therefore, that in future meridian observations should not be necessary for stars fainter than magnitude 8·5 and that for richer regions the limit may be drawn at considerably brighter stars. The observation of sufficient stars for the reduction of plates covering an area of 25 square degrees, say one star per square degree, should be ample. The new *Albany Catalogue* will come close to, but not quite reach, this number. It should not be beyond the power of existing meridian instruments to obtain accurate places of the 40,000 stars required for the photographic plates. These plates would then give the accurate positions of any other stars required, say for the reduction of plates covering 4 square degrees or less. The real task of meridian observations seems to be to determine with the utmost possible accuracy—free from systematic errors—the positions and motions of some 1500 fundamental stars and to link them closely with the 40,000

stars used in reducing photographic plates. As indicated above, photography may well come to the help of the meridian observer in determining the systematic errors of our fundamental catalogues from observations of minor planets, and, as Schlesinger has proved, the diffraction grating can be used to get over the difficulty in the measurement of the images of excessively bright stars. J. J.

Nova Herculis 1934

The most outstanding nova of recent years was discovered by Mr. Prentice at Stowmarket at 4^h 30^m on 1934 December 13. Ordinarily a faint variable star about 14^m–$14^m.6$, it was $3^m.4$ at discovery. The last known photograph of the surrounding region taken before discovery showed it to have been fainter than $13^m.8$ on November 14. At 21^h on the evening before the discovery the Rev. W. F. A. Ellison, Director of the Armagh Observatory, was observing the region of the sky between Vega and the head of Draco with the naked eye; the Moon was not quite at first quarter, south of the equator and more than 3 hours west of the meridian; the sky was clear, and as nothing exceptional was observed it may be assumed that 7·5 hours before discovery the nova was not much brighter than 6^m.

The nova brightened, with oscillations, to a principal maximum of $1^m.3$ on Dec. 22, then dropped rapidly to $3^m.4$ on Dec. 26. During January it fluctuated between $3^m.4$ and $1^m.8$, the two principal maxima being on Jan. 8 and 19; a period of 4 to 5 days was indicated, but not too clearly, with superposed oscillations of shorter period. A prolonged minimum from Jan. 30 to Feb. 6 gave its lowest value $4^m.0$ on Feb. 2, a faintness not reached again until Mar. 4—the brightest maximum in February was $2^m.5$ on Feb. 9; in early March the star oscillated irregularly about $4^m.0$ until Mar. 17, when a rapid drop took place to $5^m.4$ on Mar. 20, followed by a rise to $3^m.9$ on Mar. 26. No simple period is suggested by the rapid irregular fluctuations in brightness from Feb. 1 to Mar. 31. On the latter date a very rapid drop in brightness set in from $4^m.4$ to $8^m.2$ on Apr. 6, the star then falling somewhat irregularly to a deep minimum at $13^m.4$ on May 3. From that date the star rose again gradually to $7^m.0$ in early July, and it has oscillated slightly about $6^m.8$ from July to the end of the year. In this marked and prolonged second brightening this nova resembles N. Aurigæ 1891.

Deviations of the continuous spectrum from a black-body curve make temperature estimates at different stages of the nova's history very uncertain; information as to successive outer layers or shells can be obtained from the bright bands and absorption lines appearing at successive stages. These may in their turn lead back to the temperature of the exciting source of the radiation.

The early spectral changes of the nova proved very interesting. Owing to the promptness of Mr. Prentice in telephoning his discovery to the Royal Observatory, Greenwich, and to the skilful energy of Mr. E. G. Martin, a spectrum was obtained before dawn on the morning of discovery, Dec. 13. The spectrum was of the usual early nova type, bright bands flanked with absorptions on the side of shorter wave-lengths. The spectrum was of

B type ; the strongest emission lines were the Balmer series (*Hα* extremely broad), *He*I (5876 and 4471 broad), and *C*II 4267 ; lines of *O*II and *N*II were also present. The line *Ca*II 3933 was not visible. The spectrum was slitless, so velocities are not completely reliable. If the velocities could be taken from the intervals—emission centre *minus* absorption centre—the hydrogen velocities ranged from −900 km./sec. for *Hζ* to −1980 km./sec. for *Hα*, the velocities increasing with the wave-length ; the broad lines of *He*I gave a velocity of −1400 km./sec., while the lines of *C*II, *N*II and *O*II gave an average velocity of −700 km./sec. (with a range of −600 to −800 km./sec.).*

By 18^h on Dec. 13 the star's spectrum had changed markedly ; the bright *He*I bands had gone, and only one or two of the B-type lines survived weakly ; the bright hydrogen lines narrowed slightly by the fading of a fainter red wing ; *Ca*II 3933 and *Mg*II 4481 were becoming prominent in emission and absorption, and a number of *Fe*II lines strong in α Cygni were showing weakly in emission. A similar change from B type to A type was found on first discovery in the case of N. Persei 1901. On the morning of the 14th, when the first slit spectrograms were obtained at Cambridge and Edinburgh, these changes were more marked ; faint traces were measured of *C*II 4267, *He*I 4471 and *N*II 4447 of the B-type lines ; next to the hydrogen lines much the strongest absorption lines were *Mg*II 4481 and *Ca*II 3933 ; the *Fe*II lines were seen hazy in emission and shallow in absorption.† The velocities of approach of the absorption lines were −530 km./sec. for *H*, −414 for *Fe*II and −367 for *Mg*II ; the bright bands were on the average only displaced by 1 A. to the red of their normal positions. The drop in the velocities of approach shown by the absorption lines during the first day continued to Dec. 21, when the velocities of all elements had reached a value of about −170 km./sec. Up to this date the lines of *H* and *Ca*II showed persistently higher velocities of approach than the other lines, and for the Balmer lines the velocities increased with the wave-lengths : this latter fact was noted for N. Geminorum 1912 by Dr. W. H. Wright ; this same star and N. Aquilæ 1918 also both showed a drop in velocity of the absorption lines for the first few days after discovery.

As the velocities diminished the emission lines narrowed (a natural result under the expanding shell theory) ; they also weakened to such an extent that most of them were barely visible by Dec. 21, while at the same time the absorption lines strengthened and increased very much in number ; in addition to *Fe*II and *Ca*II, *Ti*II and *Cr*II were now represented by numerous lines, and other elements present included *Si*II, *Sr*II, *Sc*II, *V*II, *Y*II, *O*I, *Na*I, *Fe*I. The drop from maximum brightness was accompanied by the emergence on the night of Dec. 23–24, at first as a set of weak narrow absorption lines, of a second absorption spectrum, absorption II, displaced with a velocity of −300 km./sec., which during the next three months was to increase to nearly −400 km./sec.

* If the velocities are taken from the intervals (centre of emission and absorption *minus* centre of absorption) these values should be diminished by about 25 per cent.

† This spectrum has been generally described by others as absorption I.

Absorption II was of later type than absorption I, resembling closely that of ϵ Aurigæ ; for a few days (Dec. 24–29) it was accompanied by a number of similarly displaced absorption bands due to cyanogen, and the star's spectrum was intermediate between F and R types ; the cyanogen bands were at maximum strength on Dec. 26, the date of a minimum in the light-curve. Bright bands strengthened again generally and covered the lines of absorption I, which were last seen on Dec. 26. The spectrum was now a single spectrum of the usual nova nature of type F5. The displacement of the lines was rather larger for the stronger lines and for the elements of higher ionization potential.

During the first half of January absorption III appeared, a set of broad displaced lines with velocities varying from −700 to −900 km./sec. At first seen only with *H* and *Ca*II, by Jan. 15 it was found in *Fe*II, *Ti*II also, and provided the strongest lines in the spectrum. In the case of many lines it subsequently became double, and after fluctuating in strength it died out as a broad shading at the beginning of February (except for the lines of *H*, *Ca*II and a few lines of *Fe*II, where it was still strong), leaving absorption II as the principal surviving absorption. Along with absorption III there came the usual widening of the emission lines ; in the second half of February the emission bands extended to the violet of the surviving lines of absorption III for *H* and *Ca*II, and there was a suggestion of a weak, more displaced absorption at −1100 km./sec.

Meanwhile an important change had taken place in the bright bands due to *Fe*II and [*O*I], the latter of which, weakly present since Dec. 26, had become some of the strongest lines in the spectrum : two bright narrow maxima displaced with velocities ± 300 km./sec., traceable in some cases back to the end of December, had become conspicuous ; by the end of January the violet of the two maxima had narrowed down the absorption II line of *Fe*II to a very fine line, which could be seen in only a few cases and which died out completely by the beginning of March. The velocity of separation of the bright maxima was slightly higher for the [*O*I] bright lines at 5577, 6300, 6364 A. than for the *Fe*II lines, and higher still for the [*N*II] band at 5755 A. when it emerged slightly later. Similar maxima appeared in some of the *H* and *Ca*II bands, but they were frequently masked by other features and the evidence is confused. No such maxima appeared in the emission bands of *Ti*II, *Sc*II, etc., which were generally weaker than the *Fe*II bands, the *Ti*II absorption lines remaining strong after the *Fe*II absorption lines had weakened and vanished.

In the first week of March absorption IV appeared, a B-type spectrum displaced with a velocity of −900 km./sec. About this time the bright band at 4640 A. began to be prominent. The hydrogen lines now reached a stage of maximum complexity, no fewer than seven separate absorption components being measurable. Towards the end of March the bright lines of [*Fe*II], prominent in η Carinæ and in N. Pictoris 1925, appeared. These lines were all displaced to the violet along with the violet maxima of the *Fe*II bands, which at the beginning of April were much stronger than the red maxima. When the star's continuous spectrum faded with the great

drop in the star's brightness in the first week of April, the spectrum became a displaced η Carinæ emission spectrum. The *Fe*II lines next faded, followed by the [*Fe*II] lines, and all of them had vanished before minimum was reached on May 3. The hydrogen lines also weakened during the third week in April, leaving the [*O*I] line at 6300 A. as the strongest line in the spectrum. Meanwhile on April 24 the nebular lines of [*O*III] at 4363, 4959 and 5007 A. had been detected, and these steadily brightened along with the hydrogen lines as the star became brighter again ; the [*O*I] lines weakened but other bright lines appeared, due to *C*II–IV, *N*II–V, *O*II–V, [*Ne*III], [*Ne*IV], *Si*III–IV, *S*II and perhaps [*S*II], *A*IV–V. The *N*III, *He*I and *He*II lines were seen on May 18, while the *O*III lines appeared slightly later. The bright bands of the nebular stage changed very little during the second half of the year ; they contain several maxima of which the strongest gives a velocity of -300 km./sec.

No growing disc has so far been reported round the nova. Duplicity in the nucleus, looked for in vain up to June, was detected by Kuiper at the Lick Observatory on July 4. The two stellar nuclei differed in magnitude by $0^{m}\cdot4$, and the separation in p.a. 130° was $0''\cdot2$. During the remainder of the year the p.a. remained unchanged but the separation slowly increased, the estimated rate of separation being about $0''\cdot27$ a year.

The parallax of the nova has been estimated in a number of ways. From the strength of the interstellar K line E. G. Williams derived a value of 370 parsecs, giving an absolute magnitude at maximum of $-6^{m}\cdot5$. The lack of spherical symmetry implied in the formation of the two nuclei makes very uncertain a determination of the parallax by equating the velocity of separation across the line of sight with the radial velocities $\pm$ 300 km./sec. in the line of sight observed for the two chief maxima ; the value obtained in this way is 700 parsecs. Accepting Williams's parallax as the more reliable, this implies that the direction of separation of the two nuclei makes an angle of 30° with the line of sight.

It remains to be seen whether the two nuclei are two stars into which the original star has broken, or whether they are gaseous condensations driven out from the parent star in opposite directions and stimulated to radiation by excitation from a faint parent star now become a white dwarf. Further developments will be awaited with keen interest.

The foregoing account is from published papers supplemented by unpublished material at Greenwich and Cambridge.

F. J. M. S.

Planetary Atmospheres

I. *Visual and Photographic Observations*

A large amount of visual and photographic work has been done in recent years in the study of the atmospheric phenomena shown by the planets. A short account of the main results achieved is given in the following notes.

Mercury.—The idea that this planet—in consequence of the low velocity

of escape at its surface—has practically no atmosphere has been found to require some modification. E. M. Antoniadi, discussing the observations made by him with the 0·83-m. refractor at Meudon in the years 1924 and 1929, has found that some of the surface features of the planet are liable to be temporarily concealed as though by some sort of cloud. The same thing had been recorded by Schiaparelli. Dealing with his own observations quantitatively and adopting a scale of 0 (never concealed) to 100, Antoniadi has derived values for the individual features, the extremes being 5 for *Solitudo Hermæ Trismegisti* and 45 for *Solitudo Criophori*—a portion of Schiaparelli's "figure 5." These effects, it is suggested, may be due to dust particles raised by wind (*B.A.A.J.*, **45**, 236, 1935). In any case they must be taken as evidence that the planet has not yet entirely lost its atmosphere.

Venus.—Antoniadi has also discussed in *B.A.A.J.*, **44**, 341, 1934, his observations of Venus with the Meudon refractor in 1928 and 1929. Finding that certain dusky markings are sometimes seen in the same positions relatively to the terminator or limb on successive days, and apparently remain stationary, he is led to believe that the rotation period of the planet is probably a long one, that the atmosphere contains cloud masses drifting in different layers, that complete openings in these strata rarely if ever occur, but that the cloud development is related to the nature of the underlying surface of the planet. He believes that the dusky areas are at a lower level than the brighter regions since they are observed to indent the terminator, an effect which he does not consider can be wholly explained as due to irradiation.

It will be recalled that the extensive series of photographs of Venus taken in blue or violet light by Ross at Mount Wilson and at Flagstaff in 1927 and 1928 (*Ap. J.*, **68**, 57, 1928; *P.A.*, **36**, 299, 1928, and **37**, 326, 1929) showed dusky markings which exhibited somewhat quick changes, and may well have been due to temporary thinnings or partial openings in the cloudy strata.

Mars.—Apart from the unsuccessful search for spectroscopic evidence of oxygen and water-vapour mentioned in Part II, no new information has apparently been gained during the last few years concerning the atmosphere of this planet. It is now generally recognized, as indicated by photographs taken in light of various wave-lengths, that it is of greater density than was at one time thought probable. In addition there are several records of cloud areas and regions partially concealed by haze among the published papers relating to the planet's physical features. Particular mention may be made here of the cloud observed at Meudon by Antoniadi on 1933 April 14. It projected from the terminator above Eridania and reached a height of about 35 km. (*L'Astronomie*, 1933 August).

Jupiter.—It has long been known that the cloudy surface of Jupiter is controlled by a number of sharply defined currents moving parallel to the Equator, and that although objects in the Equatorial region indicate in general a rotation in approximately 5 minutes less than markings situated elsewhere, the relation between period and latitude is quite irregular and the distribution of the currents in the N. and S. hemispheres entirely

dissimilar. Recent years, however, have been made notable by the occurrence of exceptional phenomena which have added much to our knowledge concerning the development and drift of Jovian features, and attention is drawn to some of these in the following paragraphs.

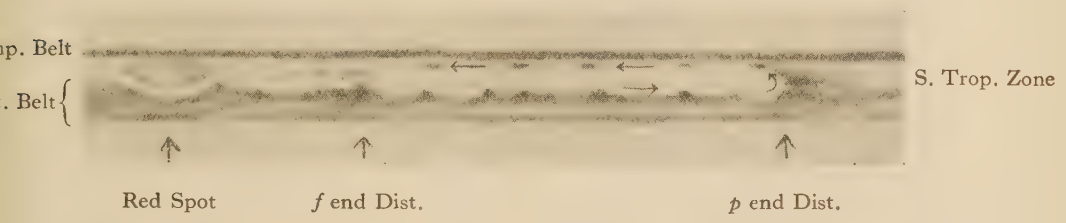
In 1926 and 1927 the region of the planet's surface between the N. edge of the S. Equatorial belt and the S. Temperate belt was apparently concealed by white clouds, though the Red Spot stood out with great prominence and had regained much of its warm tone. But when in 1928 the S. Equatorial belt, with the "hollow" or "bay" on its S. side in which the Red Spot usually lies, reappeared, the accompanying phenomena showed that the recovery was much more than the mere clearing away of a stratum of cloud. The change began with an eruption of small dark spots in the latitude of the S. edge of the S. Equatorial belt, some of which had a retrograde motion relatively to the adopted zero meridian (System II) of as much as 5° *per diem*. This means that their rotation periods actually exceeded $9^h\ 59^m$—a longer period than had previously been recorded of Jovian spots. It seems to be a reasonable inference that these objects had been ejected from a considerable depth below the planet's cloudy surface. At the same time this exceptional outbreak was accompanied by the development of spots at the N. edge of the belt, and, since the front of this latter disturbance travelled forward nearly at the rate of the Equatorial current, the ends of the two streams overlapped in longitude in about seven weeks, the greater part of the reviving belt meanwhile becoming the scene of such turbulence and violent change that it was quite impossible to follow up the individual features or identify them at successive presentations. A number of photographs taken about this time at Flagstaff show in wonderful detail the extent and rapidity of the changes, and corroborate in a most gratifying way details recorded in the visual observations.

Among other phenomena observed during the process of the great revival of activity were the occurrence of a large white cloud within the N. edge of the S. Equatorial belt, a portion of which, when at a distance of 70° or more from the central meridian of the disc, "irradiated" and often appeared as a projection at the limb ; the development and drift of large masses of reddish- or tawny-coloured but partly transparent vapour ; and other colour changes. In general, the visual records of colour are well corroborated by a fine series of colour-filter photographs taken at the Lick Observatory (*M.N.*, **89**, 703, 1929). For a detailed account of the phenomena above mentioned see the "27th Report of the B.A.A. Jupiter Section" (*B.A.A. Memoirs*, vol. xxx, part iv, 1935), and a paper (dealing with the observations of 1928 August to October), "The Revival of Activity in the Southern Hemisphere of Jupiter," by F. J. Hargreaves, B. M. Peek and T. E. R. Phillips, in *M.N.*, **89**, 209, 1928.

But the phenomena above described, though on a more notable scale, very closely resembled what had occurred at the revival of activity in the same region in 1919–20. The sequence of events, however, did not follow quite the same order, and on the later occasion it extended over six years, viz. 1928–34. A comparison of the two series of phenomena is given in the

"27th Report of the B.A.A. Jupiter Section" (p. 217), but it may be noted here that both were characterized by violent eruptions, abnormal rotation periods, clouds "irradiating" at or near the planet's limb, and what appears to have been a circulatory drift of spots recorded on no other occasions. This last atmospheric movement seems to call for some special description.

It will be remembered that one of the most conspicuous features of Jupiter during the last thirty-five years has been the S. Tropical Disturbance—a dusky area on the S. Tropical Zone between the S. Equatorial and S. Temperate belts. In the course of time this has become extended over more than 200° in longitude, and is now exceedingly feeble except at its *p* end. Now at both revivals this end seems to have presented a barrier to rapidly retrograding spots (two in 1920, a large number in 1931 and succeeding



years) at the S. edge of the S. Equatorial belt, and to have forced them southwards to the other side of the zone along which they have travelled rapidly with reversed direction of motion close to the N. edge of the S. Temperate belt. Unfortunately, for neither occasion can a complete circulation be established. The observations in 1920 are relatively few and only show the turning-point at the *p* end of the Disturbance (see "22nd Report of the B.A.A. Jupiter Section," p. 77, in *B.A.A. Memoirs*, vol. xxvi, part iv, 1926, and a paper by B. M. Peek in *B.A.A.J.*, **37**, 62, 1926), while in 1931 and subsequently the spots on their return journey either became merged with some stationary shadings on the zone or passed beneath them. A detailed account of the phenomenon has not yet been published, but the general nature of the drift which, if really complete, might be described as a very elongated anticyclone is indicated in the accompanying diagram.

One of the most interesting regions of Jupiter's surface is that between approximate latitudes +20° and +30°. This includes the N. Temperate belt, which sometimes appears double and may then show a very great contrast in the rate of drift at its N. and S. edges.

In 1881, 1890–91, 1926 (one spot) and 1929 outbreaks of spots occurred at the S. edge with rotation periods as short as $9^h\ 48^m$–$49^m \pm$, which is considerably less than that of normal Equatorial spots ($9^h\ 50\frac{1}{2}^m \pm$). On the other hand, spots at or close to the N. edge of the belt may, and commonly do, have periods of $9^h\ 56^m+$. A discussion by B. M. Peek of the 1929 rapidly moving spots is published in *M.N.*, **91**, 941, 1931. In 1928 and again in 1931–32 spots on the belt, which was then single, showed an intermediate period of approximately $9^h\ 53^m$—a value not previously recorded; while in 1929 F. J. Hargreaves found some unusually swiftly moving objects on the N.

Temperate Zone. It would seem that conditions in these regions of the N. hemisphere are subject to considerable instability.

There is obviously a great deal that remains to be cleared up concerning the atmospheric currents of Jupiter. One question which arises is whether their recorded variations of rate show evidence of periodic or secular change. A. Stanley Williams, whose classic paper "On the Drift of the Surface Material of Jupiter in Different Latitudes" (*M.N.*, **56**, 143, 1896) has been the inspiration of the last 40 years' work in this field, has been investigating the problem. His inquiry is not yet completed, but he has found some grounds for belief in a periodicity of a little over 12 years in the case of the N. Tropical Current (*M.N.*, **93**, 409, 1933), and short oscillations in about $2\frac{1}{2}$ years for both the N. and S. parts of the Great Equatorial Current (*M.N.*, **94**, 240, 1934, and **95**, 723, 1935). It will be recalled that several years ago he found evidence of periodicities in approximately 12 years in the colour changes of the two Equatorial belts and the Equatorial Zone (*M.N.*, **59**, 376, 1899; **80**, 467, 1920; **90**, 696, 1930). These questions are of much interest and call for further inquiry in the light of later observations.

Saturn.—Another opportunity of studying atmospheric movements on Saturn was presented by the appearance in 1933 of the white Equatorial spot detected independently by W. T. Hay and A. Weber, and that which followed it, seen first at Flagstaff. A full discussion by B. M. Peek of all the available observations is given in *B.A.A.J.*, **44**, 220, 1934. It appears from a comparison of all the determinations of the planet's rotation from the time of W. Herschel that the Equatorial regions have a period of about $10\frac{1}{4}$ hours, but that in comparatively high latitudes the period is very considerably greater. Observations of Barnard's spot and others in the N. hemisphere (lat. $= 35$–$40° \pm$) in 1903, which were discussed by W. F. Denning, gave $10^h\ 38^m \pm$ (*M.N.*, **64**, 239, 1904). A very similar period ($10^h\ 37^m$) has been deduced by T. E. R. Phillips for a white spot seen by him in 1910 in about the same latitude in the S. hemisphere (*B.A.A.J.*, **44**, 29, 1933); and some dark objects in the N. belt observed by M. S. Butterton in 1932 were found by him to have a period of about $10^h\ 20^m$. It is not possible in view of the scantiness of the available data to say whether or not there is a definite relationship between latitude and rotational drift, but it is evident that the differences between the periods are much greater than in the case of Jupiter.

Uranus and Neptune.—Nothing is known about the nature of the atmospheric circulation of these planets. They have a greenish-blue colour caused by the strong methane absorption in the less refrangible parts of their spectra.

Pluto.—It seems probable that this planet has an atmosphere, but its nature is entirely unknown.

Desiderata.—Among the problems presented by the greater planets for which solutions are particularly desired are the following:—

(*a*) An explanation of the colours and colour changes shown by Jupiter and Saturn. The brilliant discoveries of the presence of methane and ammonia in their atmospheres give no account of these phenomena.

(*b*) The relative levels of the Jovian features. It would seem that much

help could be given here by continued series of colour-filter photographs in combination with visual observations.

(*c*) The nature of the Red Spot on Jupiter. There is now available a very large mass of information concerning its changes in form and colour, its motion, and its relations with the S. Tropical Disturbance. The theory that the spot is a vortex, though satisfactory in some respects, is seemingly at variance with its frequently observed aspect as a lozenge-shaped area with sharply pointed *p* and *f* ends. That it extends upwards from the lower depths of the cloudy strata to the highest levels seems clearly indicated by its increasing strength in the colour-filter photographs from the infra-red to the ultra-violet. That it is not fixed in relation to a solid interior is shown by its drift. Relatively to the adopted zero meridian of System II its longitude increased from 0° in 1894 to 47° in 1903, but the direction of motion then became reversed, and, while showing large variations of velocity (which have usually been associated with conjunctions of the spot and S. Tropical Disturbance), the object has passed in the direction of diminishing longitude through zero three times, viz. in 1910, 1919 and 1927. Its rotation period has ranged from $9^h\ 55^m\ 41^s{\cdot}6$ about 1899 to $9^h\ 55^m\ 32^s{\cdot}2$ between the oppositions of 1924 and 1925, when its longitude diminished by 81° in the 13 months.

(*d*) A satisfactory explanation of the apparent discrepancy between the manifestations of energy indicated by Jovian phenomena (and in a less degree by the markings on Saturn) and the recent views of the physical condition of the greater planets based on theoretical deductions from their rotation and figure.

(*e*) Systematic physical observations in the S. hemisphere in years when Jupiter and Saturn are unfavourably placed for northern observers.

T. E. R. P.

II. *Spectroscopic Observations*

The spectroscopic method for the qualitative and quantitative analysis of gases in the atmospheres of the planets has important limitations. The available bands have at best very small absorption coefficients. The oxygen bands in the near infra-red, for example, represent an electronic transition, but a "forbidden" one in which the lifetime of the upper state is about seven seconds (Childs and Mecke, *Zeit. f. Physik*, **68**, 344, 1931). The oxygen band which lies near λ 12,650 is also forbidden. The observable bands of all other gases that have so far been detected are high harmonics of the oscillation-rotation band system, and their absorption coefficients are probably less than one-thousandth of those for the fundamentals. There are gases which have strongly absorbed bands in the visible part of the spectrum such as NO_2, ClO_2, etc., but these are very active chemically and have not been detected on the planets. The ozone in the Earth's atmosphere forms the one exception.

The Earth's atmosphere is a very serious obstacle, since its absorption short of λ 3000 completely obscures the great electronic band system of H_2, O_2, N_2, CO, etc., and the ultimate lines of the monatomic gases *He*,

Ne, *A*, etc. Moreover, the strong absorption by telluric O_2 and H_2O would effectually conceal any but very strong absorption by these gases on the planets were it not for the Doppler shift near quadrature (or elongation). The ingenious device of taking advantage of the relative velocity of Earth and planet to separate telluric and planetary lines was first suggested by Lowell (*Lowell Obs. Bull.*, No. 17, 1905), and was tried by Campbell and Albrecht (*Lick Obs. Bull.*, No. 180, 1910). It has been employed at Mount Wilson more recently, where an attempt has been made not only to find displacements of the telluric lines, but also to detect distortions of their shapes due to blending by possible planetary lines.

The spectroscopic test for the existence of an atmosphere is, on account of these limitations, by no means the most delicate one. The polar caps, brightening toward the limb, and occasional clouds on Mars, for example, prove conclusively that this planet has an atmosphere, although its main constituent has not yet been identified spectroscopically. What makes it possible to analyse planetary atmospheres at all is their great transparency in comparison with the ionized gases of stellar atmospheres, whose opacity is more than 1000 times as great. The depth to the visible surface and the mean pressure are proportionately greater in the case of the planets.

The spectrum of Mercury has been observed (Adams and Dunham, *P.A.S.P.*, **44**, 380, 1932) but no evidence of an atmosphere has been found.

In the atmosphere of Venus observations made up to the present time indicate that the amounts of O_2 and H_2O must be less than one-thousandth and one-tenth, respectively, of the amounts present in the Earth's atmosphere (St. John and Nicholson, *Ap. J.*, **56**, 380, 1922). Observations now in progress may lead to more accurate estimates (positive or negative). Carbon dioxide is known to exist in considerable amount (Adams and Dunham, *P.A.S.P.*, **44**, 243, 1932) in the atmosphere of the planet, although the bands are actually much less conspicuous than the published illustration suggests. They show clearly with a 9-foot camera in the first-order spectrum, but are difficult to detect when a 40-inch camera is used. It is of interest to note that the molecule was first identified by its moment of inertia computed from the rotational structure of the bands. These represent oscillation-rotation combinations between the ground-level and the $5\nu_3$ and $5\nu_3+(\nu_1, 2\nu_2)$ levels. Dunham (*Carnegie Inst. of Wash. Year-Book*, No. 31, 154, 1932) has compared the planetary spectrum with the absorption of 40 metres of CO_2 at a pressure of 10 atmospheres, and estimates the amount of the gas above the visible surface of the planet to be approximately 400 metre-atmospheres. Adel and Slipher (*Phys. Rev.*, **46**, 240, 1934) estimate that the amount may be as much as two mile-atmospheres. In order to avoid serious pressure effects it is necessary to make laboratory comparisons at relatively low pressure and in a much longer pipe. This will be done in the near future.

There is now little doubt that the polar caps of Mars are composed of frozen water, since the temperature is known to be too high to permit the existence of carbon dioxide snow. The red colour of the surface strongly suggests the presence of ferric iron in minerals which may be due to weather-

ing in an atmosphere which at one time contained free oxygen. Nevertheless, neither of these substances has so far been detected by the spectroscope. Microphotometer profiles show (Adams and Dunham, *Ap. J.*, **79**, 308, 1934) no certain evidence of the presence of O_2, and indicate that its amount in the Martian atmosphere is less than one per cent. of that above an equal area on Earth. For water-vapour the evidence is also negative, and could be made comparable in precision. To observe the edge of the shrinking polar cap is theoretically very desirable—but practically very difficult in ordinary seeing with large telescopes, especially during the recent winter oppositions. No evidence of CO_2 has yet been found, but the spectrograms were obtained with the 40-inch camera which barely showed the bands in Venus.

Conspicuous bands in the spectra of the major planets were discovered very early by Secchi and Huggins. The observation by Huggins (*Proc. Roy. Soc.*, **19**, 488, 1871) that $H\beta$ is strengthened in Uranus was correct. It was not until more than fifty years (Menzel, *P.A.S.P.*, **42**, 228, 1930) later that it was realized that this line of atomic hydrogen could not be produced in a cold atmosphere.

Admirable spectrograms of all the major planets, showing amazingly strong bands in Uranus and Neptune, were published by V. M. Slipher (*Lowell Obs. Bull.*, No. 42) in 1929, but the origin of the bands was not known until 1932 when R. Wildt (*Göttinger Nachr., Math. Phys. Klasse*, Nos. 22 and 29, 1932 ; *Naturwissenschaften*, **20**, 857, 1932) attributed the band at λ 6450 to NH_3, and those at $\lambda\lambda$ 5430, 6190, 7260 and 8800 to CH_4. The fine structure of the bands in the spectra of Jupiter and Saturn was photographed with high dispersion by Dunham (*P.A.S.P.*, **45**, 42, 202, 1933), and was shown to agree exactly with that in laboratory spectra of NH_3 and CH_4. Slipher and Adel (*Phys. Rev.*, **46**, 902, 1934 ; **47**, 651, 1935) have recently shown that the absorption of methane accounts for all bands so far observed, even in Neptune. This is by far the most extensive oscillation-rotation band system which is known anywhere. Forty bands are represented, including harmonics to the fifteenth order and five difference bands.

The bands of NH_3 are fairly strong in Jupiter, weaker in Saturn and absent in Uranus and Neptune, which is immediately explicable by condensation at the very low temperature of the outer planets. The bands of methane grow stronger for the outer planets, possibly because the precipitation of the clouds of condensed ammonia enables us to see deeper. On Jupiter, Dunham estimates that there are approximately 10 metre-atmospheres of NH_3 and 40 metre-atmospheres of CH_4. Adel and Slipher (*Phys. Rev.*, **47**, 787, 1935) estimate the amounts of CH_4 on Jupiter, Saturn, Uranus and Neptune to be approximately $\frac{1}{2}$, $\frac{1}{2}+$, 4 and 25 mile-atmospheres.

If the partial pressure of NH_3 at Jupiter's visible surface were equal to the weight of the quantity of this gas spectroscopically determined, the temperature could not be lower than about 170° K (Dunham, *P.A.S.P.*, **46**, 231, 1934). Excess of H_2 reduces the mean molecular weight and the partial pressure of the heavier constituents. On this assumption the temperature might be as low as 150° K. The presence of molecular compounds between NH_3 and H_2O would act in the opposite direction.

The presence of hydrogen compounds in the atmospheres of the major planets and of oxygen compounds in those of the terrestrial planets, and the existence of no atmospheres at all on the satellites and asteroids, can be accounted for on general physical and chemical principles (Russell, *Science*, **81**, 1, 1935) on the assumption that all these bodies were originally similar in composition to the Sun.

H. N. R., T. D. Jr. and R. W.

Geophysics and the Royal Astronomical Society

Since 1917 meetings for the discussion of geophysical subjects have been held in the rooms of the Royal Astronomical Society, and since 1922 geophysical papers have been published by the Society in the *Geophysical Supplement* to its *Monthly Notices*. For a long time before the *Supplement* began, geophysical papers had been published by the Society in the ordinary *Monthly Notices*; Sir G. H. Darwin's paper, "The Theory of the Figure of the Earth, carried to the Second Order of Small Quantities" (1900), is a conspicuous instance.

The present system developed in a somewhat roundabout way. It appears to have begun with two meetings held at New College, Oxford, on 1917 June 12 and 13. Sir A. Schuster, Sir F. W. Dyson, Sir J. H. Jeans, Sir H. G. Lyons, Sir Napier Shaw, Profs. H. H. Turner, S. Chapman, E. B. Elliott, A. E. H. Love and Dr. G. W. Walker were present. (Later titles are given for convenience.) The resolutions passed were as follows :—

(1) That the British Association be asked to form a committee for organizing geophysical discussions during the ensuing year.

(2) That the British Association be asked to authorize the committee to co-operate with existing committees in making recommendations for the study of geophysical subjects within the Empire.

(3) That Prof. Turner be asked to transmit the resolutions to the British Association.

Prof. H. H. Turner acted as chairman and Sir James Jeans as secretary at these meetings. The British Association had long been associated with seismology through its seismological committee.

The British Association acted in accordance with these recommendations, appointed a committee and issued a leaflet, which is reprinted in full in *The Observatory* for 1917 October. The first committee consisted of the following members: Sir F. W. Dyson (chairman), Prof. S. Chapman (secretary), Dr. C. Chree, Sir Charles Close, Prof. E. B. Elliott, Sir James Jeans, Prof. A. E. H. Love, Sir Henry Lyons, Sir A. Schuster, Sir Napier Shaw, Prof. H. H. Turner and Dr. G. W. Walker. The committee met first at the rooms of the Royal Astronomical Society on 1917 August 20. The subjects considered to come within its scope were: Seiches and Tides; Atmospheric Electricity; Seismology; Terrestrial Magnetism; Constitution of the Earth's Crust and Interior; Temperature and Internal Changes of the Earth. Discussions were arranged for the year; admission was to be by ticket. (It is not clear that the tickets suggested were ever printed.) Six

discussions were held up to 1918 June, each being preceded by a meeting of the committee. Sir A. Strahan and Prof. H. F. Newall were co-opted during the year. The British Association gave a grant of £6 for the year from the Caird Fund to cover the expenses of the meetings; this was increased to £10 for the next year. All the meetings were held at the rooms of the Royal Astronomical Society.

At the meeting of the committee on 1918 April 10 a letter from Dr. Harold Jeffreys was read suggesting co-ordination of publication, so that geophysical papers should be more concentrated in a single journal. A sub-committee was appointed, consisting of Sir Arthur Eddington, Prof. A. Fowler, Col. Grove-Hills, Dr. Jeffreys, Dr. H. S. Jones, Sir Napier Shaw, Sir A. Strahan and Prof. S. Chapman. This committee met on 1918 May 8, and recommended that there should be a recognized medium of publication of papers on geophysical subjects, as well as a more effective publication of abstracts; the resolutions passed mention the British Association, the Royal Society and the Royal Astronomical Society as to be approached. The Council of the Royal Astronomical Society resolved:

(1) That the R.A.S. do for the present undertake to receive and publish papers on geophysical subjects, including Geodesy (with Pendulum Observations and Levelling); Terrestrial Magnetism (with Auroræ); Seismology and Tides; and will if necessary hold additional meetings for the purpose of reading such papers.

(2) That this resolution be formally communicated to the British Association.

On 1918 June 14 the R.A.S. Council resolved to express to the British Association the desire that the committee that had arranged the discussions for the past year should be reappointed to arrange similar meetings in the ensuing year.

A memorandum from Sir James Jeans, dated 1918 October 4, suggested a more permanent organization, involving a Geophysical Society within the R.A.S.; the R.A.S. to be asked to grant a room for meetings, while other societies should be asked to co-operate and make grants towards the cost of producing a journal. No steps appear to have been taken with regard to this suggestion, but on 1919 April 11 the R.A.S. Council appointed a Geophysical Committee, consisting of Sir Frank Dyson (chairman); Prof. S. Chapman (secretary); Sir James Jeans, Dr. H. Jeffreys, Sir Henry Lyons, Prof. H. F. Newall and Prof. H. H. Turner; the Royal Geographical Society, the Royal Meteorological Society, the Geological Society, the Physical Society and the British Astronomical Association were each asked to nominate one additional member. The first representatives of the other societies were, respectively, Sir Charles Close, Sir Napier Shaw, Mr. R. D. Oldham, Dr. W. Eccles and Mr. H. P. Hollis. The British Association Committee decided on 1919 June 17 not to ask for reappointment, and since that time the discussions have been arranged by the Geophysical Committee of the R.A.S.

The officers of the Geophysical Committee from this time have been :

Chairman		*Secretary*	
Sir F. W. Dyson	1917–1925	Prof. S. Chapman	1917–1920
Sir Gerald Lenox-Conyngham	1925–1929	Dr. Harold Jeffreys	1920–1927
Sir Gilbert T. Walker	1929–1935	Mr. W. M. H. Greaves	1927–1932
		Dr. R. Stoneley	1932–

The *Geophysical Supplement* was started by resolution of the R.A.S. Council, dated 1922 April 12. The first papers published in it were read at a Geophysical Discussion on the Focal Depths of Earthquakes on March 3. These were : by Prof. H. H. Turner, "On the Arrival of Earthquake Waves at the Antipodes" ; by Wrinch and Jeffreys, "On the Oppau Explosion" ; and by Jeffreys, "On the Pamir Earthquake." There has, however, never been any direct connection between the Geophysical Committee, which exists only to arrange discussions, and the *Geophysical Supplement*. Papers intended for the latter are communicated to the secretaries of the Society, and may be refereed by members of the committee on the recommendation of the Council, but they are never laid on the table at the meetings of the committee, and the Council decides on the desirability of publication without advice from the committee as a body. For some time this led to a difficulty about the reading of papers. Purely geophysical ones could not be adequately discussed at the ordinary meetings of the Society ; on the other hand, all the discussions for a year were usually arranged in advance, and a paper could not be read at a discussion unless it happened to fit into a subject already decided. Thus geophysical papers often escaped being discussed by any audience interested in them. This difficulty has been met by setting aside one or two meetings during the year for the reading of papers. The first attempt was on 1926 May 7, but owing to the Transport Strike only one of the four authors was able to attend. No other such meeting was held until 1931 November 27, since when there have been two a year. The attendances at these meetings have usually been rather small, but the discussions have been animated and valuable.

A further innovation was made on 1930 March 7 in the form of a joint discussion with the Geological Society. Four such meetings have been held so far, all with large audiences.

The encouragement of Geophysics by the Royal Astronomical Society is indicated to some extent by the membership. The latest list of Fellows contains 57 whose interests appear to be mainly geophysical, and 63 whose interest in Geophysics appears to be substantial but not necessarily dominant. These numbers are probably lower than the truth, as only those Fellows have been counted whose interest is positively indicated by their occupation, which is not always given or otherwise known to the present writer ; naval officers and Fellows of the Geological and Royal Meteorological Societies are included in the second class in the absence of other information. The *Geophysical Supplement* is received by 243 Fellows and Associates of the R.A.S., by 63 subscribers and by 276 institutions on the free and exchange lists. The number of members of the Society (Fellows and Associates) is

948 (1935 December). There are still many active geophysicists in the country who are not Fellows of the R.A.S., and many geophysical papers are still published in less specialized journals that would be seen by more persons interested and more easily found if they came to the *Supplement*. At present two numbers of the *Supplement* normally appear each year, but the work actually done would probably fill four or five. Meteorology and geology are not considered in these remarks, as they are adequately provided for by two of the co-operating societies. It is hoped by many that a time will come when a geophysical paper will come to the *Geophysical Supplement* as naturally as an astronomical one comes to the *Monthly Notices* or a mathematical one to the London Mathematical Society.

The possible formation of a Geophysical Society, either as a separate body or as a section of the R.A.S., has been discussed at intervals, but no steps have been taken. The present system is peculiar, but on the whole works very well, and Geophysics has much reason to be grateful to the Royal Astronomical Society for its parental care.

H. J.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE CONTRIBUTED TO THE LIBRARY, ETC., DURING THE YEAR 1935

(*Institutions exchanging publications with the R.A.S. Library are omitted from the list, in order to economise in printing*)

American Association of Variable Star Observers
Astronomical Society of South Africa
Baltic Geodetic Commission
Batavia, International Latitude Station
Bern, Schweizerische Geodätische Kommission
Bologna, Reale Accademia delle Scienze dell'Istituto
British Horological Institute
Brussels, Institut d'Astronomie de l'Université
Canada, Geodetic Survey
Canton, Observatoire de l'Université Sun Yatsen
Carloforte (Cagliari), Regia Stazione Astronomica e Geofisica
Carnegie Institution of Washington
Catania University
Cracow, Académie Polonaise des Sciences et des Lettres
Dantzig, Naturforschende Gesellschaft
Société Astronomique Flammarion de Genève
Genoa, Istituto Idrografico della Regia Marina
Gorki (Nishni-Novgorod), Verein von Freunden der Physik und Astronomie
Helsingfors, Finnisches Geodätisches Institut
Hyderabad, Nizamiah Observatory
International Astronomical Union
Kyoto Imperial University, Kwasan Observatory
London, Royal Society of Arts
London, Science Museum
Mauritius, Royal Alfred Observatory
Merate, Reale Osservatorio Astronomico
Minneapolis, Astronomical Observatory of the University of Minnesota
Mizusawa, International Latitude Observatory
Moscow, Astronomical-Geodetical Society of U.S.S.R.
Moscow, State Research Institute of Geodesy and Cartography
Nantucket, Maria Mitchell Association
Netherlands Indies Science Council
Oporto, Faculdade de Sciências
Paris, Société Française de Photographie
Peiping, National Tsing Hua University
Princeton University
Rome, Reale Accademia d'Italia
Stalinabad, Tadjik Astronomical Observatory
Talence, Observatoire
Tashkent, Astronomical Observatory
Tôhoku Imperial University, Astronomical Institute

Tokyo, National Research Council of Japan
Tokyo, Physico-Mathematical Society of Japan
Vienna, Mittelmeerstation der Wiener Universitätssternwarte
Vienna, Österreichische Kommission für die internationale Erdmessung
Warsaw, Institut d'Astronomie Pratique de l'Ecole Polytechnique
Washington, History of Science Society

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ADDRESS

Delivered by the President, Mr. J. H. Reynolds, on the award of the Gold Medal to Professor H. Kimura.

The Gold Medal has been awarded to Professor H. Kimura, Director of the International Latitude Observatory, Mizusawa, Japan, for his valuable work on the variation of latitude. It was not possible for him to be present to receive the Medal in person, but we have with us a representative from the Japanese Embassy who will transmit it to Professor Kimura.

It was discovered by a former Gold Medallist, S. C. Chandler, in the year 1891, that the latitude of a given place is subject to small variations, consisting of two parts, one with a period of a year and the other of about 14 months. Both the component terms had amplitudes of the order of a tenth of a second of arc. This was confirmed by Küstner, another of our Gold Medallists, who also devoted much time to the problem.

Following upon this discovery, observations were made at many observatories for the determination of the variation of the latitude. These scattered series of observations were collated by Albrecht, at the Centralbureau der Internationalen Erdmessung, and analysed in the form

$$\phi - \phi_0 = x \cos \lambda + y \sin \lambda,$$

ϕ, ϕ_0 denoting the observed and mean latitude at any observatory in longitude λ, measured westwards from Greenwich. From this analysis the quantities x and y were derived, enabling the variation of the latitude at any other observatory to be computed. The Tokyo Observatory was one of the observatories that contributed material for this discussion. The observations there, commencing in 1895 August, were made by our Medallist.

These investigations combined the results of observations made at stations in different latitudes, by different methods, under very diverse meteorological conditions and each using a different list of stars. It was realised that greatly improved accuracy would be obtained if a number of stations on the same parallel of latitude were available, carefully selected with respect to local topography so as to ensure that refraction effects would be equal to the north and to the south ; each observing by the Talcott method and with an instrument of the same design, specially constructed for the purpose, and with a common observing list.

In the preliminary investigations, 17 different combinations of stations were considered and finally a chain of stations on the northern parallel of latitude $+39^\circ\ 8'$ was decided upon. The observing programme was prepared in large measure by our Medallist ; it comprised twelve groups of stars, each containing eight pairs and extending over approximately two hours of right ascension. Two groups of stars were to be observed each

night, the groups being changed in cyclic order at approximately monthly intervals.

Six stations shared the observations. These were situated at Mizusawa, in Japan ; at Tschardjui, in Central Asia ; at Carloforte, in Italy ; and at Gaithersburg, Cincinnati and Ukiah, in the eastern, central and western portions of the United States respectively. Our Medallist was appointed Director of the International Latitude Station at Mizusawa, where observations were commenced at the end of 1899.

A preliminary report on the observations for the interval 1899·8–1901·0 was published by Albrecht in *Ast. Nach.*, 156, 209, 1901 (No. 3734), the results being analysed to derive the principal components of the latitude variation, x, y. It was noticed by our Medallist that the residuals at the various stations had systematic tendencies and that these were greatly reduced if the observed latitude variations were analysed in the form:

$$\phi - \phi_0 = x \cos \lambda + y \sin \lambda + z,$$

where z is a quantity that has the same value at all the stations at any given time, but varies with the time in a period of one year. The announcement of this result was made in *Ast. Nach.*, 158, 233, 1902 (No. 3783). In the definitive discussion of the observations at the International Latitude Stations for the period 1899·8–1902·0 (Vol. I of the *Resultate des Internationalen Breitendienstes*, Berlin, 1903) the z term, or the Kimura-term, as it is generally called, was included in the discussion.

The existence of a term, with an annual period in the latitude variation, has been fully substantiated by later observations, and an extensive literature has been devoted to attempts to explain its origin. The amplitude of the term is not the same at all stations, as was thought at first, and there now seems to be little doubt that the term arises in large measure from local meteorological conditions. The seasonal variations in the distribution of air over the surface of the earth and in the precipitation of snow both give rise to small though appreciable variations in latitude of an annual nature. Small effects arising from such causes as the forced oscillation of the pole due to the action of the Sun, and the diurnal change of the plumb line by the Sun also contribute to the Kimura-term.

When, after the Great War, the newly formed International Astronomical Union took over the discussion of the international observations from the Central Bureau at Potsdam, it was natural that our Medallist should be placed in charge of it, with the responsibility of co-ordinating and reducing the observations made at the different stations. Of the original six stations, only three were still in operation when Kimura was placed in charge of the work—Mizusawa, Carloforte and Ukiah. But he has been to a large extent instrumental in securing the restarting of the station at Gaithersburg and the opening of a new station at Kitab, in Russian Turkestan (in place of the former station at Tschardjui) on the northern parallel, in addition to the commencement of regular observations at two stations in the southern hemisphere on the same parallel, La Plata and Adelaide, and at a station near the equator, at Batavia. As a result of these additional stations, the

investigation of the variation of latitude is better provided for at the present time than ever before. Our Medallist has supervised with great care all the details of the observing programme.

The seventh volume of the Results of the International Latitude Service, dealing with the period 1922·7–1931·0, has recently been published by Dr. Kimura. It is of interest to note that of the observers who participated in the international latitude work at its inception, he is the only one whose name has appeared as an observer in each of the succeeding volumes that have been published.

The recent volume is based on observations made at the three stations which alone were in operation during this period. It contains a careful and exhaustive discussion ; the problem of disentangling the x and y components of the latitude variation ; the z term, which is to be regarded as a local term, differing for each station ; and the corrections to the adopted mean declinations of each star-group is dealt with in a new manner, due to Dr. Kimura himself.

Our Medallist terminated his direction of the international latitude work at the beginning of this year, after having devoted forty years of his life to the observation of latitude variation and to the investigation of the problems that it presents.

The research for which the Medal is awarded is, properly speaking, geophysical, but we have always recognised in this Society that geophysics is included in astronomy, and we have our Geophysical Meetings and the *Geophysical Supplement to the Monthly Notices.*

Mr. Hasegawa, I have much pleasure in handing you the Gold Medal for transmission to Professor Kimura, and I will ask you at the same time to give him our best wishes for health and happiness in his retirement.

ADDRESS

Delivered by the President, Mr. J. H. Reynolds, on The Galactic Nebulæ.

The President is now able to choose his own subject for the Presidential Address, and I have therefore chosen the Galactic Nebulæ for my subject on this occasion.

The relationship which exists between the dark galactic clouds, the luminous diffuse nebulosities and the involved or neighbouring stars is now generally recognised, but it has been only during the last twenty years or so that the real connection between them has become evident, owing principally to the work of Slipher and Hubble. The luminous nebulosities, such as those surrounding θ Orionis and ρ Ophiuchi, are regions on the near side of obscuring clouds, illuminated by stars within effective range. The medium composing the clouds is lit up in two ways, depending on the temperature of the stars involved. Stars of Bo type and higher temperatures excite and ionize the atoms of the cloud by intense ultra-violet radiation, the resulting characteristic radiations being principally hydrogen, oxygen (singly and doubly ionized and in the metastable state) and helium. With stars of lower temperature than B2, the illuminated cloud gives a continuous spectrum of the same type as the stars, which we may reasonably interpret as reflected light, while nebulosities surrounding intermediate stars show a combination of both types of spectrum.

Although the great advance in nebular astronomy during the present century has been entirely due to photography since the pioneer work of Common and Roberts in this country, and Keeler in America, the blotting out of the involved stars by over-exposure has had the effect of masking the apparent luminosity relationship between the stars and the surrounding nebulosity, so that some of the galactic nebulæ came to be regarded as independent formations. As an example of this I may mention Wolf's photograph of Nebula N.G.C. 7023 in Cepheus, published in the *R.A.S.* series. No one would think from the photograph that any star was involved in the nebula at all, although it is in fact the nebulosity surrounding the star B.D. 67° 1283. And this brings me to a point which I do not think has met with the consideration it deserves, and that is the real relationship between the magnitude of the star and the surrounding nebulosity. It is evident that the apparent relationship depends for one thing on distance. If, for instance, the Great Nebula in Orion were at twice its actual distance the involved stars would be reduced to a quarter of their present brightness, while the apparent luminosity of the surrounding nebulosity would be still the same as at present, although reduced in size to half its angular diameter.

There is another complication introduced by the type of instrument employed. Broadly speaking, the apparent brightness of a star in the telescope depends on aperture, while the brightness of the surrounding nebu-

losity depends on focal ratio. By using a short focus reflector or lens we can increase the intensity and extent of a nebulosity by long exposure, but the photographic result is apt to give a very erroneous impression of its real brightness, or rather faintness, and the involved stars are often lost in the photographs. A third modification is introduced by the three dimensional form of the nebulosity which makes it impossible to say what is the real local distribution of intensity in an irregular cloud-like formation. It seems, therefore, impossible to measure the true ratio of intensity between any particular point of nebulosity and involved stars, but it is possible to measure with advantage the light distribution in planetary nebulæ, as these are usually symmetrically shaped formations, and consist of concentric gaseous shells transparent to their own radiations.

The first to realise the true character of the dark obscuring clouds in the Galaxy was Barnard, who used a 6-inch short focus lens. Their extent must be enormous, as they cover many square degrees of the sky in Orion, Cygnus and other regions in and about the Galaxy. Their edges are usually luminous, although there are some well-known exceptions to this. Thus the North America Nebula in Cygnus is really the luminous edge of an extensive dark cloud. On one side of the bright edge star counts give only 10 per cent. of the number on the other, where the normal stellar background of the Galaxy is shown with little or no obscuration. The same applies to the long filaments of nebulosity N.G.C. 6960, 6992 in Cygnus, although in these cases the disparity of star counts on either side is not anything like so marked, owing either to a shallower depth of the absorbing medium, or a greater rarefaction, or both in some degree. There seem to be indeed all degrees of density of the absorbing medium between complete opacity at a shallow depth, such as the dark nebulosity near ζ Orionis, and a scarcely perceptible dimming of the stars by a light veil. It is this difference in density which makes it impossible to gauge the depth of the clouds, although there is no reason to think that their depth is of a different order from the two dimensional extent we see.

The distance of some of these clouds has been made the subject of an exhaustive study at the Lund Observatory by Gyllenberg and Schalén. Gyllenberg dealt with star counts brighter than successive magnitudes, assuming that the dispersion in absolute magnitude is small. Schalén extended this method by taking into account the spectral types of the stars, and he arrived at a quantitative estimate of the colour excess of stars involved in the clouds. He found a conspicuous reddening of involved A- and B-type stars compared with similar stars in open regions. He deduced for the cloud in Auriga centred at R.A. $4^h\ 45^m$, Dec $+36°$, that the nearer boundary was only 70 parsecs away, while for the cloud in Cygnus centred at R.A. $20^h\ 25^m$, Dec $+35°$, the nearer boundary was 600 parsecs distant. But an estimate by Baade of another part of the Cygnus obscuration came out at < 2630 parsecs, a very different and rather indefinite result, and one that makes us think that these estimates can only be indicative of the order of distance.

And now we come to the important question of the composition of these

clouds. In the case of the Orion Nebula and others giving a gaseous spectrum, we have quite definite evidence as to their nature. They consist of hydrogen, singly and doubly ionized oxygen in the metastable state, and helium. These radiations extend for a range of about 8 light years from θ Orionis if we take the usually accepted distance of 180 parsecs. As might be expected, the singly ionized oxygen represented by $\lambda\lambda$ 3727/9 extends much farther away from θ than $\lambda\lambda$ 5007, 4959, the radiations of doubly ionized oxygen. Hydrogen seems to be almost co-extensive with singly ionized oxygen, while helium is found mostly in the central regions. We have therefore to deal with elements of low atomic number, two of which form a large part of our own atmosphere, in the form of air and water vapour. It seems curious that there is not more evidence of nitrogen in these clouds, another gas of low atomic number and very widespread in our atmosphere. The explanation seems to be that singly ionized nitrogen in the metastable state has two strong radiations at $\lambda\lambda$ 6584, 6548, but no other radiations occur within accessible range. Both these radiations are conspicuous in some of the planetary nebula, although I cannot find that they have been identified in the Orion Nebula.

It has often been assumed that the clouds must consist of solid particles owing to the fact that they reflect the light of neighbouring stars, and have a strong absorbing effect. But there is definite evidence that there can be no considerable amount of solid particles in the gaseous nebulæ, as such particles would tend to absorb the radiations from the gases and would also give a continuous spectrum. As I mentioned before, it is now generally accepted that the characteristic radiations of the gaseous nebulosities are due to the ionization of the gases in the cloud by the strong radiation of ultra-violet light, or possibly by streams of electrons, emitted by the high temperature stars involved. When the effective distance limit of this ultra-violet radiation is passed, the atoms, being no longer ionized, would naturally be present in their neutral condition. There seems to be no valid reason why these neutral atoms should not form molecules, and even enter into combination with atoms of other elements to form molecules of water vapour, and if nitrogen is present, of ammonia. Owing to the low temperature of interstellar space, these molecules could hardly exist in a gaseous or liquid form. Is it not, therefore, possible that the "dust" which causes the colour excess of stars involved in or behind clouds, and reflects the light of stars of temperature lower than B2, may be particles of frozen water vapour and perhaps ammonia? At any rate all the evidence we have is that only gases of low atomic number are present, but we do not know enough of the physical conditions to answer the question. Another point of interest is the high obscuring effect of the medium composing the clouds, which is quite sufficient to obliterate the light of stars in and behind them. It is indeed probable that the actual number of the brighter stars as well as the fainter may be considerably affected by this cause in some galactic regions.

Perhaps the most extraordinary examples of the "reflexion" nebulæ are the "variable" nebulæ. Three of these are known, Hind's variable

nebula in Taurus, near T Tauri, N.G.C. 6729 in Corona Australis and Hubble's variable nebula in Monoceros. All three are connected with variable stars and dark obscuring clouds, but it is the last two that are specially interesting.

Knox-Shaw has made a detailed study of N.G.C. 6729, in the Helwân Bulletins. The dark cloud against which the variable nebula is projected is very dense, and the edge is not illuminated, although there are two conspicuous patches of luminous nebulosity surrounding two stars, which must be on the near side of the cloud. The field is interesting because the cloud just misses obscuring the star cluster N.G.C. 6723. Knox-Shaw found that the range of the variable R Coronæ was between 11·5 to 13·7 mag. The form as well as the brightness of the nebulosity varied to some extent with the magnitude of the star, but there was only a rough correlation between the two. The form of both N.G.C. 6729 and Hubble's Variable Nebula is comet-like, and is comprised irregularly within an angle of about 60°, with the variable as the apex. The appearance of both these nebulæ is as if the star is plunging forward into the dark matter of the cloud, illuminating a nebulous train behind it. There is no doubt that the illuminated areas differ in detail from time to time. They contain various bright nodules and ring-like formations, and Knox-Shaw concludes that the illumination of the nebulosity is consistent with the idea that the light of the variable star is transmitted to the cloud with the velocity of light, if a distance of about 38 parsecs is accepted. But the most striking evidence for this is afforded by Slipher's spectrographic investigation of these two variable nebulæ, for both the stars and the nebulosities gave a spectrum similar to the earlier spectra of Novæ. Slipher compares the spectrograms with that of Nova Aurigæ. Bright hydrogen lines are specially conspicuous, with absorption on the edges of shorter wave-lengths, and bright helium also appears with many other radiations found in Nova Aurigæ.

Knox-Shaw found four other irregular variable stars in the region of the cloud surrounding R Coronæ Australis, and we are tempted to think that some of the irregularity may be due to intermittent obscuration of the stars by the medium composing the cloud. The question of internal movements in the clouds themselves is one of great interest. From Campbell's spectrographic work at the Lick Observatory on differential radial velocities in various regions of the Orion Nebula, these movements, although well established, do not seem to exceed a few kilometres a second, and it is possible that radiation pressure from the neighbouring stars may be an important factor. On the other hand, the radial velocities of the luminous parts of the clouds with regard to the earth are somewhat greater. The Great Nebula in Orion is receding from us as a whole at the rate of 17 km./sec., while the brightest parts of N.G.C. 6992 are receding at the rate of 100 km./sec.

Although the planetaries give the same general type of spectrum as the gaseous diffuse nebulosities, they are totally distinct in their origin and characteristics. There is little doubt now, I think, that they originated as new stars. The concentric, or almost concentric, shells of gas were blown out from a nova at the original outburst, and have been travelling outwards

N.G.C. 7000, N. America Nebula in Cygnus (S. end). 100-in. Refl., Mt. Wilson.
1922 July 26. Exp. 5 hours.

Neb. N.G.C. 6729, Corona Australis. 30-in. Refl., Hèlwan.
1915 Sept. 3. Exp. 90 min.

J. H. Reynolds, The Galactic Nebulæ.

for many thousands of years, in most cases, at velocities slow compared with those of the original outburst. Nova Aquilæ in 1918 was the first of these outbursts to give us the clue, and Campbell's classic work on the planetaries, of which details can be found in the *L.O.* 13, gave us the corroborative evidence we wanted. It is true that Nova Persei in 1901 showed a rapidly expanding luminous shell, but this Kapteyn interpreted at the time as the passage of light outwards in a cloud. This explanation still holds good, as the parallax of this star is so small that no other seems to account for the extremely rapid growth of the shell; in six months it had expanded to an angular distance of between 6′ and 7′ from the star. The cloud which made visible the passage of light must be almost transparent, as the field of galactic stars is a normal one. This first luminous ring was followed by a much smaller nebulous envelope which had expanded to about 30″ in diameter by 1926. It is of irregular distribution, and from the curious hook-like form of its spectral lines in 1934 it is still expanding at a considerable rate.

The great majority of planetary nebulæ are almost symmetrical about an axis, and are either elliptical or circular in outline. In some cases the gases are concentrated in the outer rim of the shell, and it is not so long ago that "ring" nebulæ were differentiated from the planetaries in the catalogues, the N.G.C., for example, having a different symbol for each. The interpretation we put on their elliptical outline and often annular form seems a very obvious one to-day, but in the earlier days of visual observation they were very mysterious objects. Thus Sir John Herschel says of the "Ring" Nebula in Lyra that "Lord Rossè has resolved this object into excessively minute stars, with filaments of stars adhering to its edges." Sir John made quite a shrewd guess about the "Owl" Nebula in Ursa Major, for he says, "We might therefore be induced to conclude its real constitution to be that of either a hollow spherical shell or of a flat disc, presented to us by a highly improbable coincidence in a plane precisely perpendicular to the visual ray." He goes on to say that "Arago had surmised that they might possibly be envelopes shining by reflected light from a solar body in their centre, invisible to us by the effect of its extreme distance." Sir John demurs to this explanation, quite rightly pointing out that if this were the case, the reflected light of the invisible star would also be too faint to be seen.

We know now, of course, that the central stars which are of O type, and probably dwarfs, are the cause of the illumination of these enormous globes and shells of gas, by strong radiation in the extreme ultra-violet. We owe to the *L.O.* 13 most of the investigation of the spectra of the planetaries and their central stars. The slitless spectrograph of the Crossley Reflector gave separate images along the spectrum, and the comparative diameters of these show the same sequence as the diffuse gaseous nebulæ. The smallest images are helium and doubly ionized oxygen, and the largest are singly ionized oxygen (both the oxygens in the metastable state), and hydrogen. In a good many cases singly ionized oxygen is not represented at all.

Like the new stars, the planetaries usually are found near or in the Galaxy, and their parallaxes are small. But if novæ are responsible for the

planetary nebulæ how is it that we do not find them on the sites of well-known outbursts in the past?

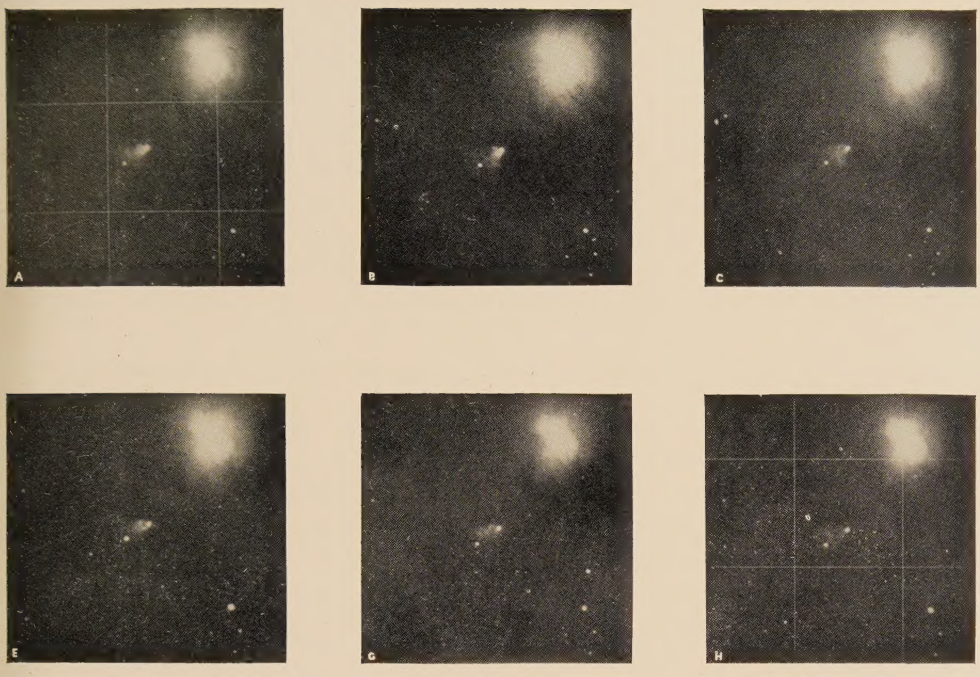
Tycho Brahe's great nova of 1572, which equalled Venus in brightness, was situated in Cassiopeia in Declination 61° 17′, and about one and a half degrees from κ, according to his observations, which were taken with great care. After allowing for precession we can determine the locality of the outburst to-day, but although a search has been made there is no trace of a planetary nebula within 8 degrees of it.

Tycho Brahe's nova was not the first in this region, for two others were reported in old chronicles, unfortunately not with the same accuracy of position, between Cassiopeia and Cepheus. One occurred in 945 A.D. and the other in 1264 A.D. Sir John Herschel put forward the suggestion of Goodricke that these and Tycho's star were the same object, a very improbable hypothesis with our present knowledge of these phenomena. Curiously enough there is a very unusual type of planetary in R.A. $23^h\ 16^m$, Dec. $+60°\ 39'$, lying about 8° away from the site of Tycho's nova, and it may be that this is the result of one of the earlier outbursts. It differs from all other planetaries in the fact that the bright illumination of the clearly defined outline over about 80° of arc is due, not to a central star, but to an 8th mag. star probably outside the shell altogether, and projected in front of it.

The contour of the rest of the disc, which is only visible in part, is about 3′ in diameter, which at a distance of 200 light years would represent a third of a light year in diameter. There is no identifiable central star, and to all appearance, if the external star were not present, the whole formation would be invisible. It would seem, therefore, that if the radiation from the central star falls below a certain temperature, and no longer extends into the ultra-violet, the whole nebular shell disappears as far as visibility is concerned. This is only what we might have expected, but we are still left with the difficulty of explaining its continued existence at all as a shell of gas, if the spheroidal form is the result of a balance between gravitation and radiation pressure, the basis of most of the theoretical work on the subject. It is possible, of course, that it is not entirely gaseous any longer, as there is some evidence of obscuration. This unique object shows us, I think, that there may be invisible as well as visible planetaries.

The researches of Keeler, Campbell, Moore, Wright and Curtis on the planetaries at the Lick Observatory were undoubtedly the most complete ever undertaken at a single observatory. Besides the direct photography with the 36-inch Crossley Reflector, and the work with the slitless spectrograph, a spectrograph with a slit and high dispersion attached to the 36-inch refractor revealed the fact that some of the planetaries were still in motion radially, and also in slow rotation.

With the slit placed across the major axis when the outline was elliptical, the lines at $\lambda\lambda$ 5007 and 4959 were found to be either doubled or widened in the middle and the ends of lines were slightly twisted in some cases. This doubling or broadening of the lines is naturally interpreted to-day as a measure of expansion or contraction, although Campbell did not agree



Neb. N.G.C. 6729, Corona Australis. 30-in. Refl., Helwan.
1913–16. Showing Variability.

Neb. N.G.C. 7635, Cassiopeia. 60-in. Refl., Mt. Wilson.
1920 Oct. 15. Exp. 3 hours.

J. H. Reynolds, The Galactic Nebulæ.

with this view, but the twisting and inclination of the lines he explained as a rotation effect.

The most striking feature of the O-type nuclear stars is their great and increasing intensity towards the ultra-violet end of the spectrum. The maximum radiation seems to be actually beyond the atmospheric limit of λ 2800, while the visual range is unusually faint. This explains why the central stars were missed in the days of visual observation, and why they come out so readily in photographs. Instead of colour excess, such as we have in the stars involved in the clouds, we find a large colour deficiency. It is difficult to give a reason for this faintness of the visual spectrum. It can hardly be actual, and we are led to think that there must be some physical effect in the mechanism of excitation of the gaseous shell which weakens the transmission of the longer wave-lengths but allows the ultra-violet to pass without loss of energy.

In conclusion I should like to refer to some of the theoretical work which has been done by Zanstra and Ambarzumian on the planetaries. Zanstra's theory of nebular luminosity is based on the idea that all quanta emitted from the central star having frequencies greater than the limit of the Lyman series are absorbed by the hydrogen atoms in the nebula. The nebulous shell re-emits these quanta as La-quanta, La being the first line of the Lyman series of hydrogen. Owing to the large optical thickness of the nebula in the La-line, and to the fact that all La-quanta absorbed are re-emitted in the same frequency, the density of the radiation in the inner layers of the shell is very large. Radiation pressure due to this radiation is therefore preponderant and much larger than the effect of gravitation from the central star.

But according to this theory the radiation pressure is much greater than observation would warrant, for it would produce an expansion of 200 km./sec. in the envelope of a planetary nebula of 10,000 astronomical units radius. The observational evidence is that the expansion (or contraction) is only 10 km./sec. on the average. Zanstra finds that for an expanding and rotating globe of gas other considerations come in, and a reduction of the theoretical velocity of expansion in agreement with observation can be obtained if the thermal width is much smaller than the luminous width. After an exhaustive mathematical and physical investigation he concludes that equilibrium in a nebulous shell round a central star can only be obtained if it is expanding and rotating at the same time.

It is impossible in a short survey like this to deal with many of the points of interest, but I have included what seem to me to be the more important results of recent investigations.

Erratum

M.N., 96, 194, 2nd footnote, *for* $P = K\rho^{1+\frac{l}{n}}$ *read* $P = K\rho^{1+\frac{1}{n}}$.

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